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FINAL REPORT

# Evaluation of Chemical Restraint Methods for Potential Use in Wild, Free Roaming Horses

1980

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# INTRODUCTION

In the spring of 1978, a study was begun on the Washington State University campus for the purpose of evaluating chemical restraint methods for potential use in wild horses. The work continued through the summer of 1980 and included much field work at BLM facilities and wild horse ranges in Oregon and Idaho. Although much was already known about chemical restraint in domestic horses, the techniques required were not appropraite for use in unapproachable horses. Therefore, methods were needed to effect immobilization in horses without first restraining them for injections.

If this could be accomplished, wild horses could be captured or restrained when conventional methods were unavailable or ineffective. It was not known whether chemical capture techniques used in other species were effective in the horse. Potential immobilizing agents were tested first in domestic horses and those which were effective were tested in wild horses under semi-confirmed conditions and later under actual field conditions. Attempts were made to evaluate drugs and techniques on the basis of rate of success as well as safety to the horse and operator. Based on results obtained from several drugs early in the study, the neuromuscular blocking agent, succinylcholine appeared to fit the criteria established for an acceptable equine capture drug and so much time and effort was expended in developing and evaluating methodology for its use in wild horses.

Following are discussions and evaluations of the chemical restraining agents tested in domestic and wild horses during this study. Included as an addendum to this report is a special evaluation of succinylcholine immobilization in wild horses and domestic control groups. Certain physiologic parameters relative to physical and emotional stress are considered in groups of horses after single and multiple episodes of succinylcholine immobilization. This special study was the primary responsibility of L.V. Gallagher and the work therein described was conducted as an M.S. thesis project. It contains a literature review on succinylcholine and the physiologic parameters used to help evaluate the capture methods. Methods of analysis and rationale for the use of those parameters to evaluate capture stress are also given in the addendum.

A listing of the drugs and equipment used in the immobilization studies can be found in the appendix.

## Immobilization Studies with Gallamine Triethiodide in Domestic and Wild Horses (Table 3)

Gallamine has a long history as neuromuscular blocking agent, immobilizing or capture drug. It is presently used by the i.v. route in human and veterinary medicine in conjunction with general anesthesia as a skeletal muscle relaxant during certain surgical procedures. It has been used intramuscularly as a capture drug in many wild animal species, including equids. The skeletal muscle blocking properties of gallamine are caused by its effect on the skeletal neuromuscle junction where it exerts a non-depolarizing effect, which is seen in the animal as a flaccid paralysis. Because its'mechanism of action is non-depolarizing, the effects can be antagonized through the competitive action of acetylcholine, the neurotransmitter. Thus, cholinesterase inhibiting agents, such as neostigmine are effective antagonists of gallamine. Twenty nine experiments, 21 in domestic and 8 with darts in wild horses were done to assess the potential use of gallamine as a capture drug in the wild horse.

A 10% solution of gallamine triethiodide (Flaxedil $^R$) administered intramuscularly at 0.5 to 0.6 mg/lb was effective in immobilizing domestic and wild horses. The effects produced, however, are quite variable in both induction and recovery times;$^1$ recurring episodes of immobilization are common and the horse usually exhibits muscle tremors (sometimes severe), sweating and an exaggerated awkward gait prior to recumbency. Horses experienced up to 6 recurring episodes in 2 or more hours prior to recovery. This effect is attributed to a very prolonged i.m. absorption time which is consistent with large hydrophilic molecular structures such as gallamine. Absorption appears to be enhanced by increased activity, thus while the horse is inactive (immobilized, resting or restrained) absorption is slow, temporary recovery occurs and the horse becomes ambulatory. When he becomes more active, absorption increases and the neuromuscular effects are seen again.

Most of the neuromuscular effects, including possible respiratory paralysis, can be antagonized with the cholinesterase inhibitor, neostigmine (Stiglyn $^R$) at least temporarily. Neostigmine is a carbamic acid derivative and as such is very short acting relative to gallamine. Neostigmine is rapidly biotransformed to an inactive metabolite, whereas gallamine is not metabolized, but circulates until excreted by renal filtration. These differences in drug distribution are seen in practice as an antagonism which has only temporary effects followed by recurrence of gallamine effects. Antagonists such as alkylphosphates, which are longer acting than neostigmines may not be feasible because of the many adverse effects on the autonomic nervous system which are common to these drugs. Horses treated with alkylphosphates would also be susceptible to adverse potentiation of succinylcholine, should it be used in the same horse during the next several days or weeks.

While there may be some potential use of gallamine in wild horses under controlled conditions, it is unlikely that it would be useful on a routine basis. The induction times are usually too long, effects too prolonged and antagonism is incomplete and temporary. Although relatively safe from fatal overdose, most horses experience for extended periods, partial paralysis and obvious discomfort. Horses would likely travel a considerable distance during the induction period and could easily wander into hazardous areas while partially paralyzed.

## Immobilization Studies with d-Tubocurarine (curare) in Domestic and Wild Horses (Table 4)

Curare is the prototype of the non-depolarizing skeletal muscle relaxant drugs. It is a naturally occurring substance which is extracted from the chondodendron vine which grows in the Amazon river basin of South America and was developed by the natives of that area as a weapon for use in catching game and in hostile activities against each other. The drug (actually several alkaloids of similar chemical structures) administered on the tip of an arrow or dart would cause paralysis in birds, monkeys, etc. after a period of time and could be caught. The game could be consumed safely because curare is so poorly absorbed from the intestines. It has been used as a laboratory tool to help explain the functions of the neuromuscular junction and as an adjunct to general anesthesia intravenously to produce a profound skeletal muscle relaxation.

Chemically, curare is a very large molecule, which delays absorption from any site and prolongs distribution and excretion. Because its' blockade on the neuromuscular junction is non-depolarizing, the effect can be antagonized by cholinesterase inhibitors, such as neostigmine. For this reason, attempts were made to establish an adequate dosage in the horse.

Curare has a relatively low solubility in water (about 5% is maximum) but a higher concentration was prepared using dimethyl sulfoxide as a solvent. Several intramuscular injections, using doses extrapolated from the literature were ineffective, so an intravenous dosage was then established as a base. Some results were finally achieved using an I.M. dose, but could not be relied upon to give consistent results. The activity of the horse apparently had an effect on absorption, since immobilization occurred in some only when exercised or when a small quantity of curare was administered I.V. Intramuscular curare used in 2 wild horses after succinylcholine immobilization experienced very prolonged effects. At this time, it is not known whether curare could be successfully used as a capture drug or as an extender of the immobilization period. There are some serious difficulties with absorption and excretion which prevent the drug from being reliably used in the horse.

## Immobilization Studies with Etorphine (M-99) by Intramuscular Injection in Domestic Horses (Table 5, 16; Figures 6, 7)

Etorphine is an opium derivative with 1000 times the sedative potency of morphine. It has been successfully used as a capture drug in many species including elephant, antelope, elk, deer and burros; it is highly toxic to humans. Etorphine in combination with acetylpromazine (Immobilon R) is commonly used in Europe as an I.V. injection for immobilizing horses for minor surgery and diagnostic procedures. Immobilization with etorphine, as other opiates is effectively antagonized with drugs which can compete successfully with etorphine for its tissue receptor sites. Diprenorphine (M-50-50) is a very successful etorphine antagonist. Etophine and diprenophine are closely regulated controlled substances and are available in the United States only in the 0.1% (M-99) and 0.2% (M-50-50) solutions. The Immobilon R product available in Europe contains 0.225% M-99 and 1.0% acetylpromazine. The reported dosage of M-99 in the horse varies from 4.5 to 22.5 mg per 1000 lbs (i.e. 2-10 ml of Immobilon), which is much higher than other species. Six experiments were done with M-99, using doses from 5 to 22.5 mg in 1000 to 1100 lb horses. In 4 experiments, acetylpromazine (Acepromazine R) was administered in quantities that would result in the same proportion of M-99 to acetylpromazine found in Immobilon.

The intramuscular use of M-99, although eventually effective, caused some serious side effects which would probably render it useless under most conditions for wild horse use. The general picture of a horse under the influence of M-99, being absorbed from an I.M. site is that of a very tense, almost rigid animal, with labored respiration, flared nostrils, hyperemic mucous membranes, pounding heart and very forcibly and blindly moving in one direction until stopped by a halter rope or an obstruction in his path. Induction time, from injection to recumbency varied from 10 to 51 minutes; the 10 mg dose was the same as the 22.5 mg dose relative to induction time as well as overall effects. In general the major effects of M-99 were antagonized almost immediately following an I.V. injection of M-50-50; two other narcotic antagonists, nalorphine and naloxone were used but required much larger doses. The horses experienced elevated body temperatures, heart rates and respiratory rates after the immobilizations were antagonized. During the immobile phase, repiration was slow but very labored. Blood pressures, measured by the doppler system, using a tail cuff were at least 2 to 3 times what they were prior to M-99 injection. In all cases, the M-99 immobilizations were antagonized as soon as readings were taken, since the effects appeared to be so severe.

Blood samples were taken from each horse prior to M-99 injection, as soon as the horse became recumbent and at 1 hour, 2 hours, and 24 hours after recumbency. Serum cortisol, SGOT, LDH and CPK values were determined in each sample. Serum catecholamines were not obtained for these experiments because the CAT serum samples were lost in a low temperature freezer which malfunctioned. Values obtained from the serum samples are listed in table 16; Cortisol and CPK values are shown in figures 6 and 7.

The cortisol means show a trend toward increasing values during the first 2 hours but are not significantly different. The 24 hour cortisol is significantly lower than the down time and 1 hour sample, indicating a return to lower normal levels.

CPK activity increased significantly for the first 2 hours after recumbency; the 24 hour mean has increased more yet, but the sample variance was very high. CPK activity responds a little slower than cortisol, but appears to be a valid indicator of physical stress or intense muscular activity.

LDH and SGOT mean activities were elevated at 24 hours but the confidence limits overlap the earlier values.

A larger number of horses may have provided data with narrower confidence limits and perhaps more specific differences. The trends and differences shown, however, appear to be consistent with the effects seen in the horses.

In conclusion, etorphine administered intramuscularly does not produce an immobilizing response which could be considered safe for the horse or the operator. Under many field conditions, it would seem that a horse under the influence of M-99 would not become recumbent soon enough to keep from injuring himself on obstacles or falling from elevations. The effects can certainly be antagonized, once the horse has become recumbent, but a less than adequate dose or a partially absorbed dose would lead to an even more excited state. Further work would have to be done to determine the usefullness of M-99 in field situations. Because M-99 is so highly toxic to humans, the work would have to be closely controlled. Very small accidental doses of M-99 have been lethal to workers. The concentration of M-99 in Immobilon would be much more practical and perhaps more effective for use in projectile syringes, but the hazard to human life would also be increased.

## Immobilization Studies with Decamethonium Bromide (C-10) in Domestic Horses (Table 6)

Decamethonium is a neuromuscular blocking agent with a mechanism of action similar to succinylcholine; it causes skeletal muscle relaxation by a depolarizing effect at the neuromuscular junction. Decamethonium has been used as a skeletal muscle relaxant as an adjunct to general anesthesia in human medicine, but is not used in veterinary medical practice. The potential for respiratory paralysis exists and because there are no chemical antagonists available which can be used to reverse the neuromuscular blockade, resuscitation methods would have to be available.

Only 2 experiments were done with decamethonium before it became evident that serious adverse effects occurred in the horse. Both horses were successfully immobilized (1 by I.V. and 1 by I.M. injection) but both developed obvious clinical signs of colic. The I.M. injection also produced effects similar to that seen with gallamine; prolonged induction with recurring episodes of immobilization accompanied by tremors, sweating, and unsteady gait. In experiment D-2, neostigmine was used to alleviate intestinal stasis associated with colic; not as an antagonist. The gastro-intestinal effects seen may have resulted from an autonomic ganglia blocking property of decamethonium. It was concluded that decamethonium could not be used effectively as a capture drug in the horse without further work to study means of preventing adverse gastro-intestinal effects.

## Immobilization Studies with Succinylcholine Chloride by Intramuscular Injection in Domestic Horses
## (With General Observations on Capture Supplies and Technique)
## (Table 7)

Succinylcholine chloride is a depolarizing neuromuscular blocking agent which has seen much use as a skeletal muscle relaxant in human and veterinary surgery in patients under general anesthesia. It has been used as an immobilizing drug by intravenous administration in the horse and as a capture drug in many species. Succinylcholine is rapidly absorbed from intramuscular injection sites and rapidly metabolized by plasma pseudocholinesterases. It produces a neuromuscular blocking effect on all skeletal muscle, thus the diaphragm and intercostal muscles may be affected enough to cause respiratory distress or asphyxia. Anoxia resulting from paralysis of respiratory muscles can be relieved by the use of artificial resuscitation. Doses less than required for immobilization (recumbency) are not detrimental; no adverse effects are seen as with the opiates or non-depolarizing muscle relaxants.

A total of 77 experiments with succinylcholine were done in domestic horses, first to assess the intramuscular absorption in the horse, duration of effect, etc. Later experiments compared the effectiveness of different concentrations of the drug, determined the best sites for injection and developed techniques for administering the drug by projectile syringe or dart (Table 7).

All but 5 of these experiments were done at WSU animal facilities with domestic horses, most of which were purchased for this project. The number of different horses and experiments done are summarized in Table 14. Five thoroughbred mares (S-62 to S-67) turned loose on a large pasture/range area, which could not be caught by conventional methods, were captured with succinylcholine administered by darts.

It soon became evident that succinylcholine administered intramuscularly, could be used to effect a rapid immobilization and recovery in the horse. Based on 33 of these experiments, one could expect to immobilize a domestic horse for 5.8 to 10.6 minutes after a 2.7 to 3.8 minute induction time with succinylcholine administered by syringe in the lateral neck muscles (Table 17). Injections made by darts in the rump region in some of the same horses gave slightly shorter time periods.

The solution used initially was 2% (Sucostrin®-2%) but was soon replaced by a 10% solution (Sucostrin®-High Potency) because the smaller volumes allowed would be more appropriate for darts and the results seemed to be more consistent. A few other concentrations were tried (15-40%) using a dry powdered form of succinylcholine (Anectine®) and reconstituting to the appropriate volume. This was done primarily to test a small volume non-reusable dart (Pneu-dart®), which will be discussed later. Anectine reconstituted to 10% appeared to be just as effective as 10% Sucostrin in all experiments with domestic and wild horses.

Resuscitation equipment and techniques were tested in immobilized domestic horses. Devices designed to deliver cylinder oxygen and/or air are very effective in relieving or preventing anoxia induced by respiratory paralysis. However, it was determined that a simple bellows operated by hand is a very efficient method of resuscitation in most horses under most conditions. It is very portable, not easily damaged and easy to operate with minimal training or experience. A horse can be adequately ventilated through an endotracheal tube or through a tube inserted into the ventral nasal meatus with alternate closing of the opposite nasal opening. An oxygen tank (various shapes and sizes) fitted with a reducing valve and flow meter to operate at approximately 50 psi and 20 to 40 liters per minute (depending on the size of horse) used in conjunction with a respirator (Bird®) or demand valve (Hudson®) is then attached to the endotracheal tube or intranasal tube and operated until the horse regains respiration. These systems are portable, but often cumbersome and require properly functioning mechanical equipment, adequately filled tanks and trained personnel to operate effectively. A simple bellows with a 2-4 liter capacity (i.e., Avon® raft pump) which can be fitted with a 3 ft. hose tipped with an 8 inch length of 18 to 25 mm i.d. smooth rubber tubing is very effective in delivering ambient air in sufficient volumes to resuscitate an anoxic horse or foal. This system is most easily operated by 2 persons. One person pumps and the other inserts and holds one nares closed around the tube, while alternately opening and closing the opposite nares as the bellows is operated. Using this method, a horse can easily be ventilated until normal respirations are resumed, which would usually be only a few minutes.

Doses as low as 15 mg/100 lbs. were effective in some horses and doses as high as 30 mg/100 lbs. did not lead to respiratory distress in many horses; 32.5 mg/100 lbs. did not cause respiratory distress in one horse. Depending on condition of the horse, amount of exercise preceeding injection, site and rate of absorption (i.e., injection in a highly vascular area and/or active horse) doses as low as 15-20 mg/100 lbs. may appear to require assisted ventilation. It is not known how many horses which experienced shallow ventilation or temporary arrest would have recovered without assistance. We routinely began resuscitation as soon as possible if there was any doubt about the horse's ability to move adequate volumes of air. On only 10 occasions during the 77 experiments (62 immobilized horses) with these domestic horses were resuscitation procedures used; 3 of those were in horses immobilized after forced exercise. Dosages of 20-25 mg/100 lbs. were effective in most horses, with some exceptions to be discussed later.

In order to extend the period of immobilization beyond that obtained with only succinylcholine, 5 of the domestic horses were administered an i.v. solution of guaifenesin and one was given appropriate doses of xylazine and ketamine intravenously. These drugs, as well as others were also used successfully in wild horses and will be described later. By using i.v. guaifenesin after initial immobilization, the period of recumbency was extended to 10 to 27 minutes, which is considerably longer than that obtained with succinylcholine alone. The horse is also somewhat sedated for a period of time after he becomes ambulatory. Because of this sedation, there is adequate time to perform diagnostic procedures, minor surgery, apply physical restraints and move into trucks, etc. before he regains his full awareness. The xylazine and ketamine combination was also effective; recumbency was extended to 28 minutes in one horse.

In order to test the potential use of succinylcholine as a capture drug, several domestic horse experiments included the use of projectile syringes (darts). Much was learned about the effectiveness of commercially available capture equipment for use on horses. In general, the Palmer equipment with certain modifications proved to be satisfactory for most long range (5-45 yds.) use and a pole syringe for closer work where the horse could not be injected with a hand held syringe.

Five different capture guns were tried on targets and horses; the Palmer $CO_2$ and cartridge gun, the Simmons gun, the Pneudart rifle and the Pax Arms equipment. All but Pax Arms rifle utilizes standard 50 calibre or 0.5 inch diameter dart cylinders. The Pneu-Dart gun is designed for special non-reusable darts, but will accept a Palmer dart. The Simmons gun is designed to use barrels of several different sizes, so can be used with any darts. The Pax Arms system was designed for use with darts of certain diameters, none of which is the 50 calibre size. The Palmer cartridge gun utilizes .22 calibre blank cartridges of various load strengths in an adapter, which is pushed into the chamber behind the dart. As the distance varies, different cartridges must be used in order to reach the target with the same force and trajectory. This can be very awkward at times, but most capture work involves firing at a distance which can be predicted soon enough to change cartridges if necessary. The Palmer $CO_2$ gun is effective for only very short distances. Also, the $CO_2$ charges vary with use and with ambient temperature and so that gun was not very useful to us. The other three guns are designed to use a standard strength cartridge, but have an adjustment for varying the speed and force that the dart is propelled. This is done by turning a knob on the breech, which allows a portion of the gases from the cartridge to be vented off. This adjustment can be made easily just before firing and if a person gains experience with the gun it can be used to advantage.

Four different sights were used on the capture guns, standard iron sights, peep sight, telescopic and illuminous dot (Qwik-Point®). Of these, the peep sight and Qwik-Point were most effective under most conditions. Of course, personal preference and conditions of use would vary, but the Qwik-Point allows one to view the entire horse while picking out a target area, it can be done quickly with a moving target and/or operator (i.e., helicopter).

The darts used most were the standard Palmer darts with modified needles and sometimes a Simmons tail piece. The Pneu-Dart Company produces 2 non-reusable darts for use in their rifle. One contains dry succinylcholine in a depression along the solid needle, which is uncovered at impact and allowed to absorb into the tissues. The maximum quantity of succinylcholine available on these darts is not sufficient for many horses. Also, absorption would be slower and problems of keeping the dart in the muscle long enough would be expected. The other Pneu-Dart syringe dart is self-contained, fires on impact, can be propelled for long distances at high velocity, but has a very small drug capacity (0.7 cc) and has difficulty holding in the horse. Because of the small capacity, a high drug concentration is necessary. A higher drug concentration decreases any margin of safety which you may have after estimating body weights. Also, absorption characteristics vary from that which was seen with larger volumes.

The Pax Arms dart utilizes air compressed into the syringe behind the plunger, the pressure and the drug is released into the muscle through side-opened needles as a sleeve is pushed off of the needle opening on impact. This dart has the advantage of requiring no explosive plunger load and the side-opening needle has a greater tendency to stick in the muscle, rather than being pushed back out by back pressure. However, it has no replaceable parts (tail piece and body are plastic), can develop air leaks, requires special calibre rifle barrels and is not readily available in the U.S. (manufactured in New Zealand).

The Palmer dart has replaceable tail and nose piece with needle; it utilizes an explosive plunger charge, which varies with syringe size (1-3 cc, 4-10 cc, 10-15 cc). The plunger must be lubricated and the cloth tail piece replaced as they gradually burn off with use, and incidentally, causes the trajectory of the dart to vary. The Simmons tail piece may be used in place of the cloth tail for consistency; it is a one piece molded plastic piece. Palmer nose pieces are available with various needle sizes and may be either plain, collared or barbed. For our purposes, a 1 1/8 to 1 1/2 inch, 14 gauge needle with double barbs at about half the length were most satisfactory. The needles had to be modified by us, since the commercial product was not acceptable for use in the horse. The plain or collared needle did not hold long enough to allow injection from the 3 to 5 cc syringe barrel. There was a common tendency for the darts to hit and bounce off or turn end for end as with the Pneu-Dart product. The commercial single barbed needle was subject to another problem. The barb is generally located too close to the tip, so that the needle tip is often not held in the muscle, but only in subcutaneous tissue. The drug then is injected into the subcutaneous space instead of intramuscular, which delays absorption long enough to render the dose ineffective.

The placement of darts in the horse was quite variable, especially early in the study, before complete familiarity and experience with the equipment. The types of equipment and possible adjustments and modifications are so numerous that to gain enough experience with all variations would be very time consuming. It is possible to effect adequate absorption of the drug from nearly any topical site on the horse. We have achieved normal drug responses from darts placed in such unlikely areas as the hock joint and the tip of tail, but generally the dart must be placed in a well-muscled area. From a head on or slight angle to the head, the chest (pectorals) and area along the posterior neck and anterior shoulder provide good muscled targets. From a side view, the upper foreleg (triceps, deltoid) and posterior shoulder area and the upper rear leg and hip area (biceps, gluteals) are good. From the rear and above, the upper rear leg, hip, rump, tail, head, croup, loin and lateral to the spine are potential areas for injection. In general, one should avoid the lower legs, ribs, head, throat, crest point of the hip or shoulder or any other bony projections. The drugs will generally not be absorbed from heavy connective tissue and darts will break or be repelled by bony areas. The barbed needles are easily removed with the aid of a small blade and infections are uncommon, especially when a topical anti-microbial is applied.

## Immobilization Studies with Succinylcholine by Intramuscular Injection in Utility Horses (Table 8)

In August 1978, after establishing I.M. doses of succinylcholine in domestic horses on the Pullman campus, there was an opportunity to test the immobilization procedures on a large number of horses and mules which were regularly used in pack strings by commercial outfitters and guides in the Bitteroot Mountain range of Idaho. These horses were maintained through the off seasons on range-like conditions and worked steadily through the hunting and fishing seasons. These horses generally lived a harder life than the pleasure-type horse, which we previously had to work with, and so perhaps more closely resembled the wild horse as an experimental model. The horses and mules in these herds are usually branded with a hot iron by their owners as a necessary means of identification, since lost and stolen horses are not uncommon to the region. The brands are normally applied to the hip or shoulder while the horse is restrained by physical means only, such as that which is done with other livestock. On this occasion, the horses and mules would be branded, while immobilized by succinylcholine.

Thirty six horses and eight mules were immobilized by intramuscular injection with a hand held syringe in two days. All but four horses were branded with hot irons while immobilized and blood samples were collected from the horses before succinylcholine injection and at one hour after immobilization. Based on informed estimates of body weights, there appeared to be some differences between dosages required for horses vs mules and whether the I.M. injections were made in neck or shoulder regions. Doses of 20 to 24 mg/100 lbs. were most effective for the eight mules with only one requiring respiratory assistance, while doses of 15-20 mg/100 lbs. were effective for the horses with respiratory assistance required in 19% (neck injections) and 76% (shoulder injections). Equal numbers of horses (18) received neck and shoulder injections; all but one mule was injected in the neck. The mules also seemed to require longer induction times (6.1 minutes average) compared to horses (3.8 minutes average from neck, 2.3 minutes average from shoulder). Upon close examination and statistical treatment of data, no significant difference in induction and recovery times between neck and shoulder injections could be ascertained

(Table 17), but there are some very definite trends which can be seen when the resuscitation data is also considered.

One older horse expired after he had been immobilized; signs of anoxia were not seen and he did not respond to resuscitation, which indicated the existence of a problem other than drug induced respiratory paralysis. On post mortem examination, it was determined that a large vessel in the thorax had ruptured causing acute fatal blood loss. It is not known whether that problem was drug related. In general, this exercise showed that succinylcholine could be safely used in a large number of horses, using dosages based on estimates of body weights and condition. No injuries to either horses or handlers were encountered and field procedures for resuscitating horses were effective.

## Immobilization Studies with Succinylcholine Cl in Wild Horses at Pullman, WA. (Table 9)

One hundred nineteen experiments with succinylcholine were done with 16 different wild horses obtained from the Burns district. An additional two wild horses, which had escaped from their adopted owners at Parkland, WA and Milton-Freewater, OR were recaptured using succinylcholine. Ninety-seven of these experiments were done as part of a special study on succinylcholine which is included as an addendum to this report. One horse was found dead in the pasture on the fourth day after it had last been immobilized with succinylcholine. The cause of death was thought to be an acute colic, and probably not a specific drug related problem.

Other than special study, these experiments were conducted primarily to test capture technique and equipment, succinylcholine products and concentrations, and the effectiveness of drugs used to extend the immobilization period. Twelve of these horses were sedated and castrated by conventional methods after succinylcholine immobilization. Drugs used following succinylcholine capture were guaifenesin, acetylpromazine, xylazine + ketamine, and thiamylal. Once the horse has been immobilized, most conventional methods of equine restraint, both chemical and physical, can then be applied as long as the succinylcholine effects are not potentiated. Respiratory arrest can occur if additional muscle relaxants, sedatives or anesthetics are administered before the horse has resumed normal respiration.

The surgeries performed on these horses were good illustrations of a very practical use for succinylcholine immobilization. There are few facilities in this country which have the capabilities for handling wild horses well enough to administer intravenous injections which are usually required to perform such treatments. Procedures such as leading by halter ropes and loading on trucks after sedation were developed with this group of horses and they proved to be very valuable experiences.

## Immobilization Studies with Succinylcholine Chloride in Wild Horses at Burns, Oregon (Table 10)

Many immobilization studies were done at the Burns BLM facilty and on nearby range areas. This work contributed much to our understanding of chemical restraint in wild horses of many types (size, condition, temperament) and methods of administration. Horses were immobilized with hand held syringes and projectile syringes in corrals and from helicopters. Several drug combinations for extending the succinylcholine immobilization period were tested. Many potential uses for succinylcholine immobilization were encountered, such as

1. horse processing (applying freeze brands, ageing, etc.)
2. sorting or isolating individuals for loading, treatment euthanasia, etc.
3. capturing horses on a range where no traps are usable
4. capturing horses which prevent other horses from entering traps

Extension of the immobilization period with other drugs or combinations provides time for examinations, treatments or surgery. A very effective use of other drugs following succinylcholine immobilization has been to keep the horse partially sedated after he becomes ambulatory. This procedure allows the handlers to move or load a horse with minimal physical restraint. It is often possible for 2 people on foot with halter ropes to lead a wild horse to an enclosure or loading ramp. A saddle horse and/or pickup truck were also used to guide a partially sedated horse after capture. Drugs and combinations tested as extenders of immobilization included acetylpromazine alone and with guaifenesin or xylazine, xylazine and morphine, xylazine and ketamine, and curare. Combinations of guaifenesin and acetylpromazine usually gave best results, but there are some disadvantages associated with the use of guaifenesin; these are

1. large volume (∿ 120 ml/1000 lbs)
2. not temperature stable (precipitates variably at temperatures less than 60-70% F)
3. must be administered intravenously (irritating to tissues)

From January to March 1979, 21 horses were immobilized in the BLM corrals outside of Burns while testing some of the procedures described above; all horses recovered completely.

In March 1979, 7 stallions, ages 1 through 7 years, were transported from Burns to Pullman for continued chemical restraint studies in wild horses. The 5 older stallions were first immobilized and sedated prior to loading on a horse van.

In November 1979, 94 succinylcholine immobilizations (89 different horses) were done in the Burns area. 35 of these were done from a helicopter and 58 were done with hand held syringes on horses contained in a bucking chute. The horses immobilized with the aid of a helicopter were located in several areas which had been cleared of wild horses, except for those which were successful in avoiding capture by conventional trapping methods. Five of these were senile stallions and so were euthanized with an I.V. solution when captured. 3 other horses suffered accidental death; a mare fell and suffered a broken neck, a stallion received 2 doses of succinylcholine without an adequate interval in between and the third was sedated too soon after immobilization. All others were immobilized, sedated and led to a holding pen.

58 horses, including 33 juveniles (less than 1 year old), were immobilized for the purpose of testing the use of succinylcholine as an adjunct to wild horse processing. These horses were injected in the neck or rump with hand held syringes as they stood in bucking chutes. As they became immobilized, the side panel was swung open allowing the horse to lie on its' side where it was aged, searched for identifying marks, neck shaved and prepped for freeze branding, had an I.D. number shaved on its' side and blood samples drawn by venapuncture. Of the first 39 horses (including 13 juveniles), processed in this manner, succinylcholine induction time average 1.5 to 2 minutes and recovery time 6.4 to 10.4 minutes, with only 9 requiring resuscitation. All horses handled in this way recovered completely.

In July 1980, 14 horses were immobilized on 3 ranges in the Burns region using helicopter capture methods. 3 escaped horses were immobilized on a range near the Burns corrals; 1 horse which had 2 doses within 5 minutes expired. 5 horses were immobilized on the Malheur refuge; the first one of these horses expired from an apparent overdose. The dosage used was based on inaccurate information concerning the size of horses in that group. Closer observations should have been made. 6 horses (including 1 foal) were immobilized on the Malheur river allotment about 50 miles east of Burns. These were large draft type horses which were trailed up out of the river canyon to a more level area before immobilizing. Blood samples were collected from most of those 14 horses. All of the horses which were successfully captured, except the foal, were treated with combinations of guaifenesin and acetylpromazine prior to leading with halter ropes. The foal was lifted out of the area in a cargo net under the helicopter.

## Immobilization Studies with Succinylcholine in Wild Horses at Prineville, Oregon (Table 11)

Three trips were made to Prineville, OR, to study the feasibility of capturing wild horses in the Cherry Creek area using chemical immobilization techniques. The third trip, (June, 1979) was terminated before anything was accomplished by orders given to the BLM personnel who were working with us. Apparently, all wild horse work was temporarily stopped at that time. The first two trips were highly successful relative to the information obtained, but only moderately successful relative to horses captured. One horse was successfully captured by immobilization with succinylcholine. Complete chemical restraint was then extended to 45 minutes and partial restraint to over 2 hours with guaifenesin and acetylpromazine. The horse was approached by using a decoy domestic horse, darted in the neck area, hobbled, haltered, sedated and led off on foot for 1.5 hours to a corral. Resuscitation with the bellows was needed, as the size of the horse was overestimated. This general procedure was used many times over at a later time with horses immobilized from helicopters in the Burns area.

Most attempts to dart horses in this rugged area were made on foot. A few from horseback and from a vehicle. Helicopters were not thought to be useful in this area because of rugged terrain and trees. In retrospect, I believe helicopters could be used to advantage. Many attempts to trap about 24 remaining horses on that range were unsuccessful. Driving a group of horses past dart shooters was not successful. Many horses were approached on foot to within adequate range, but for various reasons, including equipment failure, underestimate of dose and lack of skill, no other horses were captured in that area.

The Pneu-Dart equipment was not satisfactory in our hands under those conditions. Several darts were damaged on impact; they are very light weight. Those which appeared to stick well had no effect; increasing the concentration of succinylcholine for the small volume dart is undoubtedly part of the problems. In order to hit the horse with a low force so a barbless dart will hold long enough, the velocity must decrease, and therefore the trajectory must increase which makes it difficult to hit a target.

A telescopic sight (standard equipment on Pneu-Dart rifles) is very awkward to use under those conditions and resulted in lost time and lost attempts. Some problems with the Palmer equipment also became evident at about this time, such as 1) the need for double barbs, 2) burning off of cloth tail pieces, 3) leaking syringes through the needle (bone wax was used to plug the tip), 4) plungers which break through, 5) cartridges which misfire.

Some methods of attracting horses into range which appeared to have promise, but were not tested thoroughly included the use of decoy horses (stallions or mares in heat) or recorded horse sounds. Recorded animal sounds are used successfully to attract other species for photographing and observing. These methods could be used with success to attract wild horses, but would require a good knowledge of the terrain and the habits of the horses which inhabit the area.

## Immobilization Studies with Succinylcholine in Wild Horses at Burns Junction and Owyhee River Breaks, OR (Table 12)

In support of a BLM sponsored project conducted by the Squaw Butte Experiment Station (Oregon State University), 29 horses were immobilized with succinylcholine from a helicopter. The project required that certain females be immobilized, fitted with collars containing radio transmitters and released. Twenty four females were successfully immobilized, collared and released, 5 horses expired. The first 14 horses were immobilized on the Owyhee desert near Burns Junction with only 3 extra darts being fired. One horse was lost on the first day; a 20 year old stallion was darted by accident and resuscitation attempts were too late. On the second and third day horses were immobilized in the steep, rugged country of the Owyhee River breaks and the temperature had dropped to 10°F. In that area, 15 more horses were immobilized and 4 expired. Five were immobilized without incident on a relatively level area. Other than a possible overdose and difficulty with resuscitation in one horse (needed manipulation of epiglottis?) the horses appeared to suffer from a circulatory shock-like syndrome, complicated by immobilization and respiratory embarrassment. Factors contributing to this problem were:

1. the nature of the horses in the area (extremely excitable and hard running),
2. ambient temperature (very cold),
3. terrain (very steep and rugged),
4. difficulty in landing the helicopter close to the fallen horse (delayed resuscitation),
5. following or driving the herd until certain horses were singled out (in this study only certain females were desired),
6. using a second dart too soon (double dose and/or increased harrassment),
7. added harrassment in trying to keep the horse from going down a steep slope, etc. after darting.

## Immobilization of Wild Horses with Succinylcholine Cl at Challis and Salmon, Idaho (Table 13)

Studies done at Challis and Salmon, Idaho include assistance given to the BLM District personnel at the 1979 and 1980 roundups and assistance given to the Eastern Montana College study involving anti-fertility drugs in stallions. A few horses were immobilized in conjunction with the 1979 roundup, primarily for the purpose of administering a euthanasia solution to certain injured or otherwise unhealthy horses. Euthansaia solutions must generally be administered intravenously, so it is necessary to first restrain the horse. Chemical restraint (succinylcholine immobilization) is preferable to physical restaint because it is much safer for the operator and handlers. Horses which require special treatment or can't be hazed into the restraining chutes are also easily immobilized to allow I.V. sedation or processing (freeze brand). All of the horses processed through the restraining chute were blood sampled by our group to provide samples for our study as well as other work (Coggins tests for BLM, Eastern Montana and U. of Minnesota studies).

In cooperation with the Eastern Montana Study, twenty four horses were immobilized with succinylcholine from a helicopter. Of those immobilized, ten dominant stallions were injected wih an anti-fertility drug, three recovered and ran off before they could be further restrained, one was released without treatment and the remaining ten horses were lost. Of those which died, one broke his neck in a fall, one was probably overdosed and resuscitation was not used effectively, another slid on the snow into an area which could not be reached, and seven died of apparent circulatory shock including four which had been darted more than once for various reasons.

Horses which die of apparent circulatory shock do not respond to resuscitation treatment. The primary adverse effect attributed to the immobilizing drug, succinylcholine, is that of respiratory depression and asphyxia. This effect is readily detected and adequately treated by the methods we have employed. Most of the horses that died after a chase over rough, steep terrain in cold weather did not show signs of uncomplicated respiratory distress as we have dealt with before, but rather showed signs of circulatory collapse which has not been seen in our other experiments with succinylcholine. Several observations and inherent problems associated with the December capture operation of the Challis and Owyhee ranges are noted.

1. Selection of specific animals to fit pre-determined characteristics, such as dominant stallion of each band, leads to considerable harassment and running of the horses before the actual immobilization procedure begins.

2. Bands of horses were ranging at the 6000 to 8000 foot elevation level.

3. The terrain of high mountain ranges is frequently very rough with narrow ridge tops, long steep slopes to draw bottoms, and very few large flat areas. To run at full speed over this type of terrain, requires extreme effort by the horses and leads to severe over-extension. It is very difficult to properly place darts in horses moving over this very irregular terrain which also leads to increased running time.

4. After the dart has been placed, the pilot must try to keep the horse from running and falling down the steep slopes which leads to more stress for the horse and the pilot. If the horse starts down the slope before he collapses, it is often not possible to land the helicopter close enough to assist with ventilation, etc.

5. By selecting only certain horses to be darted, the time which remains for the operator to estimate the horse's weight and dosage required is too short so the gun must be pre-loaded with a dose that would be expected to be effective in most horses of the type sought. This will usually result in overdose for some and an underdose for others.

6. Aged horses and very excitable horses seem to be most susceptible to the shock syndrome as seen in these operations.

7. The Challis horses were large, strong, fat horses and required a slightly higher dose than the Burns-Owyhee horses but the winter hair coats made it more difficult to estimate weights.

Recommendations for improving helicopter-chemical capture operations include the following:

1. If specific horses are to be selected for capture, they should be identified and marked before capture is attempted. This will reduce the running time and harassment required to single out individual horses. Marking can be done with a $CO_2$ propelled point pellet.

2. Whenever possible, horses should be moved from the mountain tops to a more level area before capture attempts are made.

3. Excellent judgment of when to stop pursuit of horses, size and condition of horse relative to dose required, timely resuscitation and recognition of the shock syndrome will reduce losses to an acceptable number.

## Physiologic Responses to Succinylcholine Immobilization
(Tables 14, 15; Figures 1-5)

Attempts were made to monitor several physiologic responses in horses immobilized with succinylcholine. The reported effects of succinylcholine on the respiratory and cardiovascular systems as determined by in-vitro studies is described in the addendum. For this study, clinical observations and recordings were made when possible, attempts were made to develop a telemetric system for recording physiologic paramenters in ambulatory horses and blood samples were collected from several groups of domestic and wild horses for evaluation of blood chemical responses.

Clinical records were kept on heart rates, respiratory rates and rectal temperatures obtained before and immediately after immobilization when possible. In general, the changes observed if any were not remarkable. Variations in these parameters appeared to be relative to the horses temperament, amount of activity prior to immobilization, degree of respiratory involvement and ambient temperature. Increases in heart rate to 30% were usually seen in those horses which experienced some degree of respiratory difficulty. This response is an expected compensatory reaction of the cardiovascular system to maintain adequate blood $p^{0}2$ levels. Likewise, blood pressures measured by the Doppler system with a tail cuff, temporarily increased up to 100% or less depending on respiratory involvement. Measurements taken in this manner were often difficult or impossible because of the short duration of succinylcholine action. To extend immobilization by other means would, of course, alter the cardiovascular parameters and give erroneous values. Respiratory rates, as expected, were very dependent on the degree of respiratory muscle paralysis, if any. In those immobilizations not complicated by respiratory involvement, no significant changes were seen. Observations made in immobilized wild horses were not different from those made in domestic controls except where excessive forced exercise took place as described earlier.

Considerable effort was expended toward developing a method by which radio-telemetry could be used to evaluate the effects of immobilization on physiologic parameters, such as blood pressure. Miniature transistorized blood pressure transducers were surgically located in the carotid arteries of several horses with lead wires to receptacles opening on to the surface of the skin. The blood pressure impulses would be conducted to the receptacle and then through connecting wires to a radio transmitter fastened somewhere on the surface of the horse. A radio transmitted signal would then be picked up by a receiver and recorded on tape or chart paper. Much difficulty was encountered with this aspect of the project. After successful surgery, the transducers and receptacles remained intact for several weeks, before some were lost or damaged by the horses. By the time the rest of the system was developed to the testing stage some of receptacles and/or transducers were pulled out or damaged. A satisfactory site on the horse to locate receptacles and transmitters was not found. Damage to the receptacles occurred between tests (rubbed on feed bunks, biting, etc.) and damage to the transmitters occurred during the tests as the horse fell to the ground. Development of an antenna which could send out an uninterrupted signal from a moving, falling horse was not entirely successful. Those tests which were conducted indicated that normal blood pressure variations were so extreme that a drug induced effect would be difficult to discern. As the normal alert horse responds to changes in his surroundings, his blood pressure varies considerably. Thus, the presence of other horses or people, activity, etc. causes the blood pressure and heart rate to rise and fall. An automated cuff was also developed which could be used to take periodic blood pressure readings from the tail of an immobilized horse. This device was not completed until recently and so has not been thoroughly tested.

In order to futher evaluate the effects of succinylcholine immobilization on physiologic parameters of the horse, blood chemistry determinations were made. A commercial clinical laboratory (Treasure Valley Lab, Boise, ID), the WSU Veterinary Clinical Pathology Lab and our own research labs were utilized. Many blood chemical values were determined, but not all were useful in evaluating potentially stressful situations. Those thought to be valid indicators relating to physical and/or emotional stress are the serum enzymes LDH (lactate dehydrogenase), CPK (creatine phosphokinase), SGOT (serum glutamate oxaloacetate transaminase), cortisol and catecholamines. The role of the enzymes in skeletal muscle metabolism and their appearance in the blood as a result of excessive muscular activity, fatigue, trauma or other myopathy is described in the addendum. The function of the adrenal hormones (cortisol and catecholamines) and releasing mechanisms as they relate to stress in horses is also described in the addendum. In order to assess the possibility of delayed succinylcholine metabolism, which would cause prolonged or exaggerated drug response, serum pseudocholinesterase concentrations were also determined.

CPK values determined in groups of domestic horses before and after succinylcholine immobilization were no different for all groups except the utility horses which were hot branded during immobilization. All groups of wild horses except the ones maintained at Pullman had higher mean values of CPK than the domestic controls although 2 of the groups did not differ significantly because of large variance within the groups. The wild horses that were run into chutes before immobilization had the highest values.

The means of all wild horse groups fall outside of the reported normal CPK range for horses of 8-130 IU/Li. From these data, it would appear that the muscular exertion (physical stress) associated with helicopter hazing, running into chutes and hot branding, etc. has a greater effect on the horses' muscle physiology than the actual use of succinylcholine.

LDH activities were no different among all domestic control groups and the domestic groups were not different from most wild groups. Only the wild horses sampled at Burns had LDH activities greater than all others. The Salmon horses were intermediate in LDH activities. No conclusions can be drawn on these data.

SGOT activities detected were no different among all domestic groups. Only the Burns wild horses immobilized in the chutes had SGOT values higher than all domestic groups and all other wild groups.

In general, the results of the serum enzyme studies indicate that no major change in muscular exertion can be attributed to the use of succinylcholine as an immobilizing agent. Differences were seen between some wild horse groups and the domestic control groups. These differences, however, were not consistent with the exception of the Burns group which were recently recaptured by conventional trapping methods and later moved into chutes for immobilization and processing. It is not known whether their original capture experience was different from those captured at Salmon by conventional methods.

Serum catecholamine concentrations of all immobilized wild and domestic horses were greater than the domestic control horses. The confidence intervals, because of very great individual differences, were exceptionally wide for most of the sampled groups. Catecholamine secretions seem to vary greatly among individuals of each group in response to excitment. Because of this, it may not be feasibile to use catecholamine concentrations as an indicator of stress in horses except under the most carefully controlled conditions.

Pseudocholinesterase determinations were made on samples obtained from several different groups of captured wild horses and domestic controls. There were differences between certain groups, both domestic and wild, but no pattern of differences could be seen. Some groups of wild horses had pseudocholinesterase activities which were greater than some domestic groups and vice versa. Samples obtained in the summer or fall were not in all instances, different from those obtained in winter or spring. At this time, no correlation has been made between succinylcholine dosage and intensity of response in individuals or groups of horses.

## Evaluation of Chemical Restraint Methods for Potential Use in Wild, Free Roaming Horses
## Summary and Conclusions

All of the immobilization studies in domestic and wild horses are summarized in tables 17, 18, 19, and 20.

Skeletal muscle relaxants and sedative analgesics were tested in domestic and wild horses to determine their effectiveness as primary immobilization agents or capture drugs. Sedatives, tranquilizers and muscle relaxants were tested in domestic and wild horses as secondary extenders of immoblization and as an aid to physical restraint methods. Capture drug delivery systems were tested for effectiveness in wild horses under controlled and field conditions. Emergency resuscitation methods for use in apneic horses were tested under controlled and field conditions.

Many drugs are very effective in the horse when administered intravenously, but are not absorbed from intramuscular sites at rates which are adequate for capture work. The sedative analgesics combinations (xylazine with morphine or ketamine) are not effective as capture drugs in the horse. Intramuscular absorption is too slow to achieve a rapid, profound effect and the excitatory properties of morphine and ketamine in the horse preclude their use without a potentiator like xylazine. Diprenorphine (M-99) was not tested in the wild horse, but probably should be. Its' use in domestic horses is associated with several adverse effects, but certain advantages may prove it to be useful under field conditions. M-99 is very costly, causes some rather severe muscular and cardio-vascular responses, is not immediately effective and requires strict control and human safety standards; but, the effects can be completely antagonized.

The non-depolorizing muscle relaxants (curare and gallamine) are effective by intramuscular injection and can be antagonized at least briefly. However, because of delayed and prolonged effects which are related to slow absorption, these drugs are rather difficult to use with consistent results.

The depolarizing skeletal muscle relaxants have been shown to be most useful, but also are not used withcut certain adverse effects. Decamethonium received only limited testing, but gastro-intestinal side effects were very evident and would have to be prevented before any use could be made of the drug. Succinylcholine choloride, however, was shown to be very effective and safe under many conditions of use. The principal adverse effect associated with succinylcholine is partial or complete paralysis of the respiratory musculature. We have shown that apneic horses can be adequately ventilated for the duration of the drug effect if necessary. Dosages of succinylcholine can vary somewhat with age and physical condition of the horse, but an experienced operator can make adjustments as the work progresses. Succinylcholine effects are seen very quickly after injection, allowing one to keep the horse in sight and reach him in time for treatment if necessary. An underdose of succinylcholine is not harmful to the horse and a second dose is not cummulative if given after a reasonable time interval. Repeated immobilizations in one horse by succinylcholine at short intervals (hours) can lead to life threatening physical and biochemical sequellae, but repeated immobilizations at longer intervals (days) would not be expected to cause any problems. The only horses that expired as a direct result of immobilization were those which received an obvious overdose or had been harrassed for an extended period of time (especially at high elevation and cold temperature) by helicopter hazing. Most of those deaths were related to studies in which certain horses (adult mares, dominant stallions) were required so the hazing was prolonged. We believe most of the deaths could have been prevented with more experience in sizing up a horse, avoiding multiple doses within a few minutes, moving horses into less hazardous areas before immobilizing and marking those certain horses in advance of attempts to capture.

Other than the above mentioned problems, succinylcholine appears to meet most of the necessary criteria for capture drugs:

1. Effective soon (2-3 minutes) after an I.M. injection
2. An underdose is not harmful
3. Small volume of injection (2-3 cc per 1000 lbs.)
4. Inexpensive (average dose less than $1)
5. Readily available (not a DEA controlled substance)

6. Stable under most ambient temperatures (liquid preps have rate of deteriorization at high temperatures; dehydrated forms can be reconstituted as needed)
7. Primary adverse effect can be alleviated
8. Compatible with chemical and physical restraints used after capture
9. Can be used by qualified technicians

Succinylcholine was shown to be an effective agent for immobilizing wild horses under a variety of conditions (open range, pasture, corrals, restraining chutes) and for a variety of purposes (capture for transport, capture for examination or treatment, immobilize for freeze marking, etc). Several drugs were used as an adjunct to succinylcholine immobilization as a means of extending the immobilization period, rendering the horse more easily handled, sedating for surgery, etc. Most conventional chemical restraint methods were found to be compatible with primary succinylcholine immobilization. Combinations of guaifenesin and acetylpromazine were most useful for the purpose of transporting horses after capture.

## Recommendations for the Use of Succinylcholine Chloride

### 1. Artificial Respiration

Succinylcholine should not be used unless properly functioning resuscitation equipment is on hand. Equipment suitable for providing adequate ventilation to humans as well as horses should be available. Personnel who may be called upon to operate such equipment should be adquately trained. Succinylcholine dosages used in horses can cause respiratory paralysis in the human. The Hudson system with demand valve and face mask was designed for human emergency use until professional help can be reached. Methods of resuscitation which are effective for horses have been discussed.

### 2. Analgesics

Succinylcholine in not an analgesic. Any procedures not ordinarily performed on horses without benefit of general or local anesthesia or sedative - analgesics should, therefore, not be performed under succinylcholine immobilization alone.

### 3. Euthanasia

Succinylcholine alone is not considered to be a humane agent of euthanasia. It should be used as an aid to euthanasia only as a means of restraint while acceptable methods are used.

### 4. Operators

Succinylcholine, secondary drugs, and capture equipment should be handled only by those who have received adequate training and experience. Succinylcholine, secondary drugs, and the equipment required for use should be considered hazardous. A complete training program and certification of operators is highly recommended. The program should include discussions of the pharmacology of the drugs' actions as well as demonstrations and experience under field conditions.

5. Condition of the horse

Succinylcholine is best used in healthy, nourished, rested horses. One should avoid using the drug in debilitated, exhausted or extremely excited horses when possible. Adjustment of dosage is made to compensate for deviations from the normal.

6. Dosage

The effective I.M. dosage of succinylcholine for most horses is 15 - 30 mg/100 lbs. body weight, depending on age, size and condition of the horse. The younger, smaller and well fed, but lean horses generally require the higher doses. Smaller test doses should be used in a herd which is unfamiliar to the operator. A dose which may have been injected, but did not put the horse down should not be repeated for at least 10-15 minutes. Repeated immobilizations of a horse within one day should be avoided.

7. Site of injection

Injections of succinylcholine should only be made in heavily muscled areas of the horse. Injections made elsewhere can give inconsistent results. In general, the lateral neck, shoulder, rump and upper regions of the rear leg give best results with projectile syringes. Some differences in the rate and intensity of response may be seen between injection sites (i.e. neck vs shoulder).

8. Potentiators

In order to avoid excessive or prolonged skeletal muscle relaxation one should avoid the use of succinylcholine in horses which have been exposed to any of the following within 30 days.

a. cholinesterase inhibiting chemicals (i.e. organic phosphate or carbamate insecticides or anthelmintics, neostigmine, etc.)

b. antibiotics, the generic name of which ends in "mycin".

c. procaine

9. Storage

Solutions of succinylcholine should be refrigerated when not in use, however, 10% solutions are stable for at least 3 months at 25°C (77°F). The dehydrated forms can be kept for much longer times and rehydrated with sterile water as needed. Do not use products which have exceeded their expiration date.

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# APPENDIX

Table 1. Immobilization Studies with Morphine Sulfate - Xylazine by Intramuscular Injection in Domestic Horses, Pullman, WA

| Experiment No. | Date | Name | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Drug | Dose (mg) | Results and Comments |
|---|---|---|---|---|---|---|---|---|
| MX-1 | 6/8/78 | Big Knee | G - 1200 | 9 | Thoroughbred | Morphine<br>Xylazine | 600<br>900 | Became less alert in 15 min.<br>Carried head low<br>No further effects (9 ml dose) |
| MX-2 | 6/8/78 | Apaca | F - 900 | 8 | Appaloosa | Morphine<br>Xylazine | 450<br>675 | No further effects (6.75 ml dose) |
| MX-3 | 6/8/78 | Crackin Ice | F - 1000 | 2 | Thoroughbred | Morphine<br>Xylazine | 500<br>750 | No further effects (7.5 ml dose) |
| MX-4 | 6/9/78 a.m. | Big Knee | G - 1200 | 9 | Thoroughbred | Morphine<br>Xylazine | 767<br>1150 | Some incoordination in 8 min. |
| MX-5 | 6/9/78 a.m. | Apaca | F - 900 | 8 | Appaloosa | Morphine<br>Xylazine | 567<br>850 | Docile, slight response to needle prick |
| MX-6 | 6/9/78 a.m. | Crackin Ice | F - 1000 | 2 | Thoroughbred | Morphine<br>Xylazine | 667<br>1000 | Scuffing feet, head down in [illegible] min.<br>No response to needle prick<br>Tranquil |
| MX-7 | 6/9/78 p.m. | Big Knee | G - 1200 | 9 | Thoroughbred | Morphine<br>Xylazine | 967<br>1450 | Calm, oblivious to noise |
| MX-8 | 6/9/78 p.m. | Apaca | F - 900 | 8 | Appaloosa | Morphine<br>Xylazine | 717<br>1080 | Noticeable sedation |
| MX-9 | 6/9/78 p.m. | Crackin Ice | F - 1000 | 2 | Thoroughbred | Morphine<br>Xylazine | 834<br>1250 | Unsteady, head down, leaning<br>Head pushing |
| MX-10 | 6/10/78 a.m. | Big Knee | G - 1200 | 9 | Thoroughbred | Morphine<br>Xylazine | 1200<br>1800 | 300 mg Xylazine at 8 p.m. to quiet, was still walking |
| MX-11 | 6/10/78 a.m. | Apaca | F - 900 | 8 | Appaloosa | None | | Off feed, listless, colic at 7 p.m., oral trtm't. - abdom surgery 6/11, expired 6/12 |
| MX-12 | 6/10/78 a.m. | Crackin Ice | F - 1000 | 2 | Thoroughbred | Morphine<br>Xylazine | 1051<br>1575 | Lost balance, almost fell - still walking at 8 p.m. - gave 200 mg Xylazine to quiet. |

Table 2. Immobilization Studies with Ketamine-Xylazine by Intramuscular Injection in Domestic Horses
Pullman, WA

| Experiment No. | Date | Name | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Drug | Dose (mg) | Results and Comments |
|---|---|---|---|---|---|---|---|---|
| KX-1 | 6/8/78 | Super | F - 1100 | 7 | Quarter | Ketamine<br>Xylazine | 1000<br>500 | No visible response<br>Docile for foot trim<br>15 ml total dose |
| KX-2 | 6/8/78 | Desert Bunny | F - 1200 | 10 | Thoroughbred | Ketamine<br>Xylazine | 1200<br>600 | 15 ml total dose<br>18 ml total dose |
| KX-3 | 6/9/78 a.m. | Super | F - 1100 | 7 | Quarter | Ketamine<br>Xylazine | 1250<br>750 | Slight incoordination<br>Recovered in 30 min. |
| KX-4 | 6/9/78 a.m. | Desert Bunny | F - 1200 | 10 | Thoroughbred | Ketamine<br>Xylazine | 1600<br>850 | Unsteady gait in 5 min.<br>Lips flaccid<br>Recovered in 30 min. |
| KX-5 | 6/9/78 p.m. | Super | F - 1100 | 7 | Quarter | Ketamine<br>Xylazine | 1575<br>940 | Uncoordinated, shallow erratic respiration |
| KX-6 | 6/9/78 p.m. | Desert Bunny | F - 1200 | 10 | Thoroughbred | Ketamine<br>Xylazine | 2000<br>1060 | Unsteady |
| KX-7 | 6/10/78 a.m. | Super | F - 1100 | 7 | Quarter | Ketamine<br>Xylazine | 1000<br>1600 | Very little response |
| KX-8 | 6/10/78 a.m. | Desert Bunny | F - 1200 | 10 | Thoroughbred | Ketamine<br>Xylazine | 2500<br>1300 | Unsteady gait in 5 min. |

Table 3. Immobilization Studies with Gallamine Triethiodide in Domestic and Wild Horses
Pullman, WA

| Experiment No. | Date | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| G-1 | 6/22/78 | Big Knee | G - 1155 | 9 | Thoroughbred | 290 | Syringe-Neck | None | - | Slight tremors only |
| G-2 | 6/22/78 | Super | F - 1120 | 7 | Quarter | 280 | Syringe-Neck | None | - | Slight tremors in shoulder and flank, slight unsteady gait |
| G-3 | 6/22/78 | Crackin Ice | F - 1000 | 2 | Thoroughbred | 380 | Syringe | 21 | 14 | Tremors, unsteady gait, sweating, good muscle relaxation when down, no respiratory difficulty, recovery okay |
| G-4 | 6/23/78 | Desert Bunny | F - 1160 | 10 | Thoroughbred | 464 | Syringe-Neck | None | - | Slight tremors, anxiety |
| G-5 | 6/23/78 | Cas | F - 865 | 15 | Arab | 433 | Syringe-Neck | 11<br>18<br>2<br>1.5<br>14 | 11<br>2<br>1<br>1<br>1 | Horse was down 4 more times for short duration within 45 min., each drop accompanied by tremors, wobbly gait, sweating. |
| G-6 | 6/23/78 | Big Knee | G - 1155 | 9 | Thoroughbred | 575 | Syringe-Neck | 13<br>13 | 60<br>2 | Went down one more time when exercised. Tremors and wobbly gait. |
| G-7 | 6/25/78 | Crackin Ice | F - 1000 | 2 | Thoroughbred | 500 | Syringe-Neck | 40<br>35<br>16 | 5<br>1<br>5 | Horse was down 2 more times for short duration during the next hour. |
| G-8 | 6/26/78 | Super | F - 1120 | 7 | Quarter | 670 | Syringe-Neck | 40<br>2<br>3<br>4<br>5<br>6 | 5<br>6<br>5<br>41<br>1<br>24 | Horse was down 5 more times for short duration during the next 2 1/4 hrs. Tremors and shaking sometimes severe prior to drop. |

| Experiment No. | Date | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| G-9 | 6/27/78 | Cas | F - 865 | | Arab | 520 | Syringe-Neck | None | - | Incomplete injection, part of dose lost,no effect. |
| G-10 | 6/27/78 | Desert Bunny | F - 1160 | 10 | Thoroughbred | 700 | Syringe-Neck | 5<br>2<br>3 | 30<br>14<br>48 | Horse was down 2 more times in the next 1 3/4 hrs. Neostigmine used after second drop. |
| G-11 | 7/20/78 | Cas | F - 885 | 15 | Arab | 440 | Syringe-Neck | None | - | Not down, slight tremor and stumbling |
| G-12 | 7/24/78 | Cas | F - 885 | 15 | Arab | 440 | Syringe-Neck | None | - | No effect |
| G-13 | 7/24/78 | Desert Bunny | F - 1160 | 10 | Thoroughbred | 700 | Syringe-Neck | None | - | Not down, tremors, unsteady gait |
| G-14 | 7/24/78 | Ladies Man | G - 950 | 3 | Thoroughbred | 570 | Syringe-Neck | 11<br>111 | 28<br>25 | Down once more in 2 1/2 hrs. 3 doses neostigmine used. |
| G-15 | 8/1/78 | Super | F - 1120 | 7 | Quarter | 280 | I.V.-Jugular | 0.5 | 11 | Immediate drop, respiratory distress, resuscitated with bellows, used 1 dose neostigmine. No recurrence. |
| G-16 | 8/1/78 | Big Knee | G - 1226 | 9 | Thoroughbred | 740 | Syringe-Neck | None | - | Tremors and shaky over 1 hr. after injection. One dose neostigmine used to effect recovery. |
| G-17 | 8/7/78 | Super | F - 1120 | 7 | Quarter | 670 | Syringe-Shoulder | 5 | 13 | Sat down 20 min. later. One dose neostigmine used. |

| Experiment No. | Date | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| G-18 | 8/7/78 | Jaded Madam | F - 1200 | 18 | Thoroughbred | 720 | Syringe-Shoulder | 25<br>21<br>17<br>4<br>25 | 30<br>4<br>3<br>16<br>5 | Down 6 more times in 1 1/2 hrs. Two doses neostigmine used. Severe shaking and sweating preceded drops. |
| G-19 | 8/8/78 | Jaded Madam | F - 1200 | 18 | Thoroughbred | 720 | Syringe-Shoulder | 16<br>12 | 48<br>8 | Down 1 more time. I.V. neostigmine 7 min. prior to 1st recov. |
| G-20 | 8/8/78 | Super | F - 1120 | 7 | Quarter | 670 | Syringe-Shoulder | 23<br>22<br>3 | 15<br>2<br>2 | Down 2 more times within the next hr. |
| G-21 | 10/27/78 | Big Knee | G - 1292 | 9 | Thoroughbred | 775 | Syringe-Shoulder | 13<br>23<br>37 | 12<br>11<br>12 | Down 2 more times in next 1 1/2 hours. |
| G-22 | 6/11/80 | Blk Paint (398) | G - 300 | 2 | Wild | 330 | Dart-Brisket | 23 | 2 | Pre-down time--stiff legged, sweating, shakes. |
| G-23 (SM-59) | 6/11/80 | Sorrel Paint (407) | F - 400 | 1 | Wild | 400 | Dart-Right Hock Side | None<br>8<br>7 | <br>28<br>5 | Poor absorp. because of dart site, after 64 min. gave 100 Succ. Chol. Went down twice. Some effects of gallamine? |
| G-24 | 7/8/80 | Blk Joe (001) | G - 1000 | 7 | Wild | 600 | Dart-Shoulder | 10<br>5 | 210<br>12 | After 1 1/2 hours the horse got up every 15 min. |
| G-25 | 7/15/80 | Bay Paint (399) | G - 900 | 2 | Wild | 320<br>180 | Dart-Rump<br>10% Succ. Chol. | 53<br>23 | 14<br>30 | Prior to going down the horse stumbled followed by shaking and tremors. |

| Experiment No. | Date | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| G-26 (SM-60) | 7/15/80 | Blk Paint (398) | G - 900 | 2 | Wild | 500 | | | | Good recovery (Horse found dea 4 days later, 7/19/80). Dru related? |
| | | | | | | 200 | Rt. Rump-Succ. Chol. 10% | | | |
| | | | | | | 225 | Rt. Shoulder-Succ. Chol. 10% | | | |
| | | | | | | 270 | Lt. Rump-Succ. | 1.5 | 5.5 | |
| G-27 | 8/20/80 | Bay Paint (399) | G - 900 | 2 | Wild | 600 | Dart-Rt. Leg | 2<br>46<br>1<br>0.5 | 16<br>1<br>0.5<br>10 | Antagonist was Neostigmine. On 16 mm film. |
| G-28 | 8/20/80 | Roan Paint (401) | G - 900 | 2 | Wild | 500 | Dart-Lt. Rear | 29<br>1<br>0.5<br>20 | 1<br>1<br>4<br>0.5 | Horse up and down several times 5 cc Neostigmine used. |
| G-29 | 7/15/80 | Roan Paint (401) | G - 900 | 2 | Wild | 450 | Dart-Shoulder | None | | No effect--dart fired and fel out. |

Table 4. Immobilization Studies with d-tubocurarine in Domestic and Wild Horses

| Exper. No. | Date | Horse I.D. Name/ No. | Horse I.D. Sex - Wt. Lbs. | Horse I.D. Age Yrs. | Horse I.D. Breed Type | Soln. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C-1 | 8/9/78 | Super | F - 1120 | 7 | Quarter | 2% in water | 36 | Syringe-Shoulder | None | | No effect. |
| C-2 | 8/9/78 | Tina | F - 1050 | 3 | Morgan | 2% in water | 48 | Syringe-Neck | None | | No effect. |
| C-3 | 8/14/78 | Jaded Madam | F - 1200 | 18 | Thoroughbred | 2% in water | 72 | Syringe-Neck | None | | No effect. |
| C-4 | 8/14/78 | Super | F - 1120 | 7 | Quarter | 2% in water | 102 | Syringe-Neck | None | | No effect. |
| C-5 | 8/16/78 | Super | F - 1120 | 7 | Quarter | 2% in water | 36 | I.V. | None | | No effect. |
| C-6 | 10/26/78 | Ladies Man | G - 1100 | 3 | Thoroughbred | 4.5% in water | 50 | I.V. | 14 | 9 | Down--good respiration (32/min). |
| C-7 | 10/26/78 | Desert Bunny | F - 1160 | 10 | Thoroughbred | 4.5% in water | 54 | I.V. | None | | No effect. |
| C-8 | 10/26/78 | Tina | F - 1056 | 3 | Morgan | 4.5% in water | 54 | I.V. | None | | No effect. |
| C-9 | 10/26/78 | Big Knee | G - 1160 | 9 | Thoroughbred | 4.5% in water | 54 | I.V. | None | | No effect. |
| C-10 | 10/27/78 | Desert Bunny | F - 1166 | 10 | Thoroughbred | 4.5% in water | 72 | I.V. | None | | No effect. |
| C-11 | 10/27/78 | Tina | F - 1045 | 3 | Morgan | 4.5% in water | 64 | I.V. | 3 | 14 | Down. |

|  |  | Horse I.D. |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exper. No. | Date | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Soln. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
| C-12 | 10/27/78 | Ladies Man | G - 994 | 3 | Thorough-bred | 4.5% in water | 61 | I.V. | 1 | 25 | Down. |
| C-13 | 11/9/78 | Big Knee | G - 1287 | 9 | Thorough-bred | 4.5% in water | 90 | I.V. | 2 | 8 | Down. |
| C-14 | 11/9/78 | Ladies Man | G - 994 | 3 | Thorough-bred | 4.5% in water | 79 | I.V. | 1 | 29 | Down--O.D., respiratory arrest, 5 cc Neostigmine, oxygen, on respirator 6 min. |
| C-15 | 11/9/78 | Desert Bunny | F - 1166 | 10 | Thorough-bred | 4.5% in water | 79 | I.V. | 1 | 9 | Down. |
| C-16 | 11/20/78 | Ladies Man | G - 994 | 3 | Thorough-bred | 4.5% in water | 90 | I.M.-Shoulder | None |  | No effect. |
| C-17 | 11/20/78 | Big Knee | G - 1289 | 9 | Thorough-bred | 4.5% in water | 146 | I.M.-Shoulder | None |  | Slight effect--slight weakness, slight incoordination, phimosis. |
| C-18 | 11/20/78 | Desert Bunny | F - 1168 | 10 | Thorough-bred | 4.5% in water | 159 | I.M.-Shoulder | None |  | No effect. |
| C-19 | 11/20/78 | Tuffy | G - 1067 | 6 | Quarter | 4.5% in water | 73 | I.V. | 2 | 22 | Down--respir. arrest for 7 min., taped B.P. |
| C-20 | 11/21/78 | Ladies Man | G - 996 | 3 | Thorough-bred | 4.5% in water | 149 | I.M.-Shoulder | None |  | No effect. |
| C-21 | 11/21/78 | Big Knee | G - 1290 | 9 | Thorough-bred | 4.5% in water | 205 | I.M.-Shoulder | None |  | Slight effect--penis relaxe after 8 min. from injection. |
| C-22 | 11/21/78 | Desert Bunny | F - 1168 | 10 | Thorough-bred | 4.5% in water | 212 | I.M.-Shoulder | None |  | No effect. |

|  |  | Horse I.D. |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exper. No. | Date | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Soln. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
| C-23 | 11/21/78 | Tuffy | G - 1067 | 6 | Quarter | 5.0% in water | 230 | I.M. | None |  | No effect. |
|  |  |  |  |  |  |  | 25 | I.V. | 2.5 | 10 | Down after I.V. dose with good respiration. |
| C-24 | 11/22/78 | Desert Bunny | F - 1168 | 10 | Thoroughbred | 5.0% in water | 290 | I.M. | None |  | No effect--12.5 mg I.V. given, dragging feet noticed. |
|  |  |  |  |  |  |  | 12.5 | I.V. | None |  | Slight effect--dragging feet after 2 min. from I.V. |
| C-25 | 11/22/78 | Ladies Man | G - 996 | 3 | Thoroughbred | 5.0% in water | 294 | I.M. | None |  | No effect--this horse was captured with Succ. Choline in pasture, see S-51. |
|  |  |  |  |  |  |  | 12.5 | I.V. | 2 | 13 | Down. |
| C-26 | 11/22/78 | Big Knee | G - 1289 | 9 | Thoroughbred | 5.0% in water | 440 | I.M.-Shoulder | None |  | Slight effect--nose tremors followed 48 min. later with 10 mg I.V. |
|  |  |  |  |  |  |  | 10 | I.V. | None |  | No effect. |
| C-27 | 2/20/79 | Ladies Man | G - 990 | 3 | Thoroughbred | 5.0% in water | 225 | I.M.-Neck | None |  | No effect. |
| C-28 | 2/20/79 | Tuffy | G - 1064 | 6 | Quarter | 10% in DMSO | 339 | I.M.-Shoulder | 65 | 40 | Down with good respiration. Used Atropine and Neostigmine. up immediately, increased circulation and absorp. due to exercise? |

| | | Horse I.D. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exper. No. | Date | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Soln. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
| C-29 | 2/20/79 | Big Knee | G - 1212 | 9 | Thoroughbred | 10% in DMSO | 550 | I.M.-Shoulder | None | | No effect. |
| | | | | | | 2% in DMSO | 10 | I.V. | 28<br>25 | 30<br>10 | Down twice after I.V. given. Atropine and Neostigmine given. Good respiration. Increased absorption due to increased exercise? |
| CM-1 | 3/2/79 | 914 | F ≃ 900 | | Mustang | 10% in DMSO | 300 | I.M. | 5 | 50 | Down in 5 min., 5 cc Neostigmine after 50 min. |
| | | | | | | | | | Down again | 4.5 hr. | Horse went down again for 4.5 hours and recovered OK. |
| CM-2 | 3/2/79 | 916 | F ≃ 600 | | Mustang | 10% in DMSO | 150 | I.M. | 35 | 4.0 hr. | Respiration OK, recovery OK. |

Table 5. Immobilization Studies with Etorphine (M-99) by Intramuscular Injection in Domestic Horses, Pullman, WA

| Exper. No. | Date | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| E-1 | 4/3/80 | Desert Bunny | F - 1000 | 11 | Thoroughbred | 11.25 | I.M. Neck | 11 | 6 | Antagonized with M 50-50, 22.5 mg. Very tense, labored respir., pulls hard on lead. |
| E-2 | 4/3/80 | Black Coal | G - 1000 | 6 | Thoroughbred | 22.5 | I.M. Neck | 12 | 11 | Antagonized with M 50-50, 45 mg. B.P. from 125 to over 400 mg Hg. At 14 min. after standing HR=90, RR=160, temp. 102°F (up from 98.4°F). |
| E-3 | 8/20/80 | Desert Bunny | F - 1050 | 12 | Thoroughbred | 5 M99<br>22 Ace | I.M. Shoulder | 10 | 54 | Antagonized with a total of 100 mg Nalorphine over 1 hr. Very tense, labored respir. B.P. over 350 mm Hg (up from 128). |
| E-4 | 9/10/80 | Black Coal | G - 1100 | 7 | Thoroughbred | 5 M99<br>22.5 Ace | I.M. Shoulder | 51 | 9 | Antagonized with 100 mg Nalorphine--total. Tense, pulls hard on lead. |
| E-5 | 9/10/80 | Bullwinkle | G - 1000 | 3 | Thoroughbred | 5 M99<br>22.5 Ace | I.M. Shoulder | 43 | 6 | Down and up several times before staying down at 43 min. 100 mg Nalorphine total. |
| E-6 | 9/10/80 | Tuffy | G - 1100 | 7 | Quarter | 10 M99<br>44 Ace | I.M. Shoulder | 12 | 7 | 300 mg Nalorphine total, 10.4 mg Naloxone. Fell down several times after initial drop. Tense, labored breathing, pulls hard. |

Table 6. Immobilization Studies with Decamethonium Bromide (C-10) in Domestic Horses, Pullman, WA

| Exper. No. | Date | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Soln. | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D-1 | 8/21/80 | Big Knee | G - 1200 | 10 | Thoroughbred | 2<br>20 | I.V.<br>I.V. | None<br>1 | 28 | 0.1% in water | Waited 20 min. before second dose I.V. Good color, good resp. 14/min., 40 min. after I.V. dose the horse layed down with rolling and discomfort fo 2 hrs. Complete recovery in 4 hrs. |
| D-2 | 8/21/80 | Tuffy | G - 1100 | 7 | Quarter | 50 | I.M.<br>Neck | 17<br>7<br>5 | 12<br>12<br>5 | 10.0% | Resp. 30/min. but erratic. Tremors, shaking, sweating, no G.I. sounds, down 2 more times, Neostigmine I.V. and I.M., complete recovery in 2.5 hrs. |

Table 7. Immobilization Studies with Succinylcholine Chloride by Intramuscular Injection in Domestic Horses, Pullman, WA

| | | Horse I.D. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Exper. No. | Date | Name or No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
| S-1 | 6/29/78 | Cas | F - 865 | 15 | Arab | 173 | Syringe-Neck | 2.0 | 5.0 | 2% soln. |
| S-2 | 6/29/78 | Big Knee | G - 1155 | 9 | TB | 231 | Syringe-Neck | 1.5 | 7.0 | 2% soln., shallow respir., up easy. |
| S-3 | 6/29/78 | Super | F - 1117 | 7 | Qtr. | 224 | Syringe-Neck | 3.5 | 7.5 | 2% soln., slight tremor, shallow respir., up when stimulated. |
| S-4 | 6/29/78 | Cas | F - 865 | 15 | Arab | 173 | Dart-Rump | None | -- | Collared needle hit and bounced out. |
| S-5 | 6/30/78 | Desert Bunny | F - 1160 | 10 | TB | 232 | Syringe-Neck | None | -- | 2% soln., muscle tremors only, exercised prior. |
| S-6 | 6/30/78 | Super | F - 1117 | 7 | Qtr. | 224 | Syringe-Neck | 4.0 | 3.0 | 2% soln., exercised prior. |
| S-7 | 6/30/78 | Crackin Ice | F - 1070 | 2 | TB | 160 | Syringe-Neck | None | -- | 2% soln., no effect. |
| S-8 | 6/30/78 | Desert Bunny | F - 1160 | 10 | TB | 232 | Syringe-Neck | None | -- | 2% soln., muscle tremors front and rear for 6 min., but not down. |
| S-9 | 6/30/78 | Crackin Ice | F - 1070 | 2 | TB | 214 | Syringe-Neck | 2.0 | 4.0 | 2% soln., used bellows briefly. |
| S-10 | 7/5/78 | Desert Bunny | F - 1160 | 10 | TB | 240 | Syringe-Neck | 3.5 | 9.5 | 10% soln. used for S-10 and all following unless noted otherwise. |
| S-11 | 7/5/78 | Super | F - 1117 | 7 | Qtr. | 220 | Dart-Post Thorax | None | -- | One std. barb near tip, 2.2 cc Q.S. water in 3 cc syringe. |
| S-12 | 7/5/78 | Big Knee | G - 1155 | 9 | TB | 230 | Dart-Post Scapular | 4.0 | 5.0 | Std. barbed needle. |

| | | Horse I.D. | | | | | | Induc. | Recov. | |
|---|---|---|---|---|---|---|---|---|---|---|
| Exper. No. | Date | Name or No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Time (min.) | Time (min.) | Comments |
| S-13 | 7/6/78 | Super | F - 1117 | 7 | Qtr. | 280 | Syringe-Neck | 2.0 | 10.0 | Some paddling while down. |
| S-14 | 7/6/78 | Jaded Madam | F - 1150 | 18 | TB | 238 | Dart-Shoulder | 3.0 | 21.0 | Rear leg lameness prevented getting up sooner. |
| S-15 | 7/6/78 | Super | F - 1120 | 7 | Qtr. | 308 | Dart-Pre-Scapular | 10.0 | 4.0 | Std. barb, poor penetration, S.Q. injection? |
| S-16 | 7/6/78 | Cas | F - 865 | 15 | Arab | 238 | Dart-Intercostal | None | -- | Tremors only, not down, good penetration, poor site? B.P.=95 control. |
| S-17 | 7/6/78 | Super | F - 1120 | 7 | Qtr. | 310 | Syringe-Neck | 5.0 | 3.0 | B.P.=120 down, held down for blood sample. |
| S-18 | 7/6/78 | Cas | F - 865 | 15 | Arab | 240 | Syringe-Neck | 3.0 | 10.0 | Respir. distress, difficulty with bellows, used $O_2$ respirator. Removed dart from S-16. |
| S-19 | 7/10/78 | Big Knee | G - 1155 | 9 | TB | 346 | Syringe-Neck | 3.0 | 10.0 | |
| S-20 | 7/10/78 | Desert Bunny | F - 1160 | 10 | TB | 350 | Syringe-Neck | 4.0 | 4.0 | Respir. arrest, resus. with bellows and $O_2$ respirator. |
| S-21 | 7/10/78 | Cas | F - 865 | 15 | Arab | 220 | Syringe-Neck | 3.0 | 10.0 | |
| S-22 | 7/10/78 | Jaded Madam | F - 1150 | 18 | TB | 288 | Syringe-Neck | 1.0 | 10.0 | Lost about 0.2 cc on injection, lameness delayed time to stand. |
| S-23 | 7/11/78 | Jaded Madam | F - 1200 | 18 | TB | 240 | Syringe-Neck | 3.0 | 11.0 | Lameness delayed time to stand. |
| S-24 | 7/11/78 | Cas | F - 865 | 15 | Arab | 260 | Syringe-Neck | 3.0 | 6.0 | |
| S-25 | 7/11/78 | Super | F - 1120 | 7 | Qtr. | 340 | Syringe-Neck | 4.5 | 4.5 | |
| S-26 | 7/13/78 | Big Knee | G - 1226 | 9 | TB | 370 | Syringe-Neck | 2.0 | 8.0 | |

|  |  | Horse I.D. |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| Exper. No. | Date | Name or No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
| S-27 | 7/13/78 | Super | F - 1120 | 7 | Qtr. | 360 | Syringe-Neck | 2.0 | 10.0 | Respir. arrest, resus. with bellows, HR about 200 in arrest. |
| S-28 | 7/13/78 | Desert Bunny | F - 1160 | 10 | TB | 232 | Syringe-Neck | 2.0 | 7.0 |  |
| S-29 | 7/17/78 | Jaded Madam | F - 1200 | 18 | TB | 390 | Syringe-Neck | 2.0 | 39.0 | Respir. arrest, resus. with bellows, HR 180-200 in arrest, old horse and lean, poor metabolism? Secondary block? |
| S-30 | 7/17/78 | Big Knee | G - 1226 | 9 | TB | 115 | Syringe-Neck | None | -- | Muscle tremors only, not down. |
| S-31 | 7/17/78 | Cas | F - 865 | 15 | Arab | 150 | Syringe-Neck | 2.0 | 4.5 |  |
| S-32 | 7/17/78 | Desert Bunny | F - 1160 | 10 | TB | 174 | Syringe-Neck | 4.0 | 3.0 | Lean mare. |
| S-33 | 7/17/78 | Super | F - 1120 | 7 | Qtr. | 168 | Syringe-Neck | 5.0 | 2.0 |  |
| S-34 | 7/18/78 | Big Knee | G - 1226 | 9 | TB | 400 | Syringe-Neck | 4.0 | 11.0 | No respir. problems, sternal recumb. for 2 min. |
| S-35 | 7/18/78 | Desert Bunny | F - 1160 | 10 | TB | 145 | Syringe-Neck | 2.5 | 4.0 | Went down with difficulty. |
| S-36 | 7/18/78 | Super | F - 1120 | 7 | Qtr. | 140 | Syringe-Neck | None | -- | Defecated, not down. |
| S-37 | 7/18/78 | Jaded Madam | F - 1200 | 18 | TB | 150 | Syringe-Neck | 9.0 | 10.0 | Severe tremors, defecation. |
| S-38 | 7/18/78 | Cas | F - 885 | 15 | Arab | 110 | Syringe-Neck | None | -- | Defecated. |
| S-39 | 7/20/78 | Big Knee | M - 1226 | 9 | TB | 150 | Syringe-Neck | None | -- | Stumbled slightly. |
| S-40 | 7/20/78 | Jaded Madam | F - 1200 | 18 | TB | 120 | Syringe-Neck | None | -- | Much tremor in front legs and shoulders. |
| S-41 | 7/20/78 | Desert Bunny | F - 1160 | 10 | TB | 120 | Syringe-Neck | None | -- | Defecation, muscle tremors. |

| | | Horse I.D. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Exper. No. | Date | Name or No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
| S-42 | 7/31/78 | Super | F - 1120 | 7 | Qtr. | 170 | Syringe-Neck | 3 | 9.5 | 57 cc 40% GG, 55 mg/kg, HR-RR after recovery 40-36. |
| S-43 | 7/31/78 | Big Knee | M - 1226 | 9 | TB | 110 | Syringe-Neck | 3 | 20 | Admin. GG, respir. distress, used bellows. |
| S-44 | 8/1/78 | Jaded Madam | F - 1200 | 18 | TB | 180 | Syringe-Neck | 5 | 9 | |
| S-45 | 8/1/78 | Cas | F - 885 | 15 | Arab | 133 | Syringe-Neck | None | -- | Defecated, slight tremble. |
| S-46 | 8/16/78 | Tuffy | M - 1050 | 6 | Qtr. | 160 | Syringe-Neck | 2 | 6 | |
| S-47 | 11/15/78 | Tuffy | M - 1065 | 6 | Qtr. | 160 | Syringe-Neck | 3 | 3 | |
| S-48 | 11/17/78 | Tuffy | M - 1065 | 6 | Qtr. | 213 | Syringe-Neck | 6 | 5 | Defecated. |
| S-49 | 11/17/78 | Tuffy | M - 1065 | 6 | Qtr. | 213 | Syringe-Neck | 2 | 5 | |
| S-50 | 11/22/78 | Ms. Swabe | F - 1000 | 4 | Qtr. | 200 | Dart-Rump | 3 | 7 | Cartridge gun. |
| S-51 | 11/22/78 | Ladies Man | M - 1000 | 3 | TB | 200 | Dart-Rump | 1 | 8 | Cartridge gun, horse loose in 7 acre pasture, chased for 15 min. |
| S-52 | 1/11/79 | Ladies Man | M - 1000 | 3 | TB | 200 | Dart | 2 | 5 | Horse loose in 7 acre pasture. |
| S-53 | 3/21/79 | Ladies Man | M - 1000 | 3 | TB | 170 | Dart-Rump | 2 | 28 | Extended immobilization with 5 cc 10% xylazine I.V., 9 cc 10% ketamine I.V. |
| S-54 | 3/21/79 | White Mare | F - 850 | 10 | Arab | 170 | Dart-Rump | None | -- | Darted 3 times, 15% Anectine, 15% Anectine, 28.5% Anectine (approx. 240 mg). |
| S-55 | 3/21/79 | Big Knee | M - 1226 | 9 | TB | 240 | Dart-Stifle | 3 | 3 | 10% Anectine. |
| S-56 | 3/21/79 | Big Knee | M - 1226 | 9 | TB | 257 | Dart | 2 | 4 | 10% Anectine. |

| | | Horse I.D. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Exper. No. | Date | Name or No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
| S-57 | 3/22/79 | Desert Bunny | F - 1160 | 10 | TB | 240<br>240 | Dart<br>Dart-Rump | None<br>2 | --<br>17 | 1st dart possibly S.Q., Extended immobilization with 50% GG (110 mg/kg, 1/2 as bolus, rest in 1 min.). |
| S-58 | 3/22/79 | White Mare | F - 850 | 10 | Arab | 200 | Dart-Hip | 2 | 27 | 112 cc 40% GG, 1/2 as bolus, rest in 1 min. |
| S-59 | 3/22/79 | Tuffy | M - 1065 | 6 | Qtr. | 220 | Dart-Rump | 2 | 21 | 120 cc 40% GG, 60 cc each as bolus. |
| S-60 | 3/23/79 | Bay Filly | F - 600 | -- | -- | 200 | Dart | 3 | -- | Respir. arrest, bellows for 3 min. |
| S-61 | 3/23/79 | White Mare | F - 850 | 10 | Arab | 200 | Dart | None | -- | Some muscle fasciculation observed. |
| S-62 | 5/23/79 | -- | F - 1150 | -- | TB | 225 | Dart-Thigh | 2 | -- | S-62 through S-66 are from Ray Smith pasture on Snake River breaks near LaCrosse, WA (five horses owned by Faye C. Hubbard). |
| S-63 | 5/23/79 | -- | F - 1150 | -- | TB | 225 | Dart-Thigh | 2 | -- | |
| S-64 | 5/23/79 | -- | F - 1000 | -- | TB | 200<br>213 | Dart-Thigh<br>Dart-Thigh | None<br>2 | | |
| S-65 | 5/23/79 | -- | F - 1150 | -- | TB | 250 | Dart | 3 | -- | S-65 same as S-63. Mare broke halter and escaped after 1st capture. |
| S-66 | 5/23/79 | -- | F - 1150 | -- | TB | 225 | Dart | -- | -- | S-66 same as S-62. Broke lead rope and escaped after 1st capture. |
| S-67 | 6/11/80 | Black Coal | M - 1045 | 6 | TB | 230 | Dart-Rump | 1 | 5 | 30 sec. after horse went down. |

|  |  | Horse I.D. |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
| Exper. No. | Date | Name or No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
| SGB-1 | 7/17/79 | Tuffy | G - 1078 | 6 | Qtr. | 270 | Syringe-Rump | None | -- | SGB-1-5: Exercise control horses. Blood samples before and after forced exercise. Immobilized after exercise. |
| SGB-2 | 7/17/79 | Big Knee | G - 1235 | 9 | TB | 310 | Syringe-Rump | 2.5 | 5.5 | Assist. respir. |
| SGB-3 | 7/17/79 | Bullwinkle | G - 960 | 2 | Appy. | 240 | Syringe-Rump | 3.0 | 4.0 | Not a smooth drop. |
| SGB-4 | 7/17/79 | Black Coal | G - 1045 | 6 | TB | 260 | Syringe-Rump | 0.6 | 19.5 | Assist. respir. |
| SGB-5 | 7/17/79 | Desert Bunny | F - 1180 | 11 | TB | 295 | Syringe-Rump | 2.1 | 7.0 | Assist respir. |
| SG-100 | 2/19/80 | Bullwinkle | G - 850 | 10 | TB | 187 | Syringe-Rump | 1.8 | 7.3 | SG-100-104: Succinylcholine controls smooth induction and recoveries. Blood samples collected at t=0, down, 1 hr., 24 hr., 48 hr., 72 hr. (These horses had no experimental use for 10 months prior). |
| SG-101 | 2/19/80 | Desert Bunny | F - 1100 | 12 | TB | 242 | Syringe-Rump | 2.3 | 7.5 |  |
| SG-102 | 2/19/80 | Big Knee | G - 1150 | 10 | TB | 253 | Syringe-Rump | 1.8 | 4.0 |  |
| SG-103 | 2/19/80 | Tuffy | G - 1000 | 7 | Qtr. | 220 | Syringe-Rump | 1.5 | 6.0 |  |
| SG-104 | 2/19/80 | Black Coal | G - 1050 | 3 | TB | 231 | Syringe-Rump | 1.5 | 9.0 |  |

Table 8. Immobilization Studies with Succinylcholine Cl by Intramuscular Injection in Utility Horses at Kooskia, Idaho (8/29/78-8/30/78)

| Exper. No. | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Site of Injection | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| SV-1 | Pete | G - 950 | 6 | Appaloosa | 190 | Neck | 5.0 | 13.0 | Blood taken, branded. |
| SV-2 | Tarzan | G - 1050 | 11 | Red Appy. | 210 | Neck | 8.0 | -- | Blood taken, branded. |
| SV-3 | Socks | G - 1000 | 18 | Blk. & Wh. | 200 | Neck | 3.0 | 7.0 | Bellows used. Blood taken, branded. |
| SV-4 | Ringo | G - 1000 | 20 | Wh. Paint | 200<br>230 | Neck | 5.0 | Died | Diagnosis from post-mortem: acute hypertension with resultant vascular rupture. Branded. |
| SV-5 | Sugar | F - 900 | 6 | Grey Arab. Welch | 180 | Neck | 4.0 | 6.0 | Blood taken, branded. |
| SV-6 | Shorty | G - 850 | 13 | Roan Welch | 170 | Neck | 4.0 | 6.0 | Blood taken, branded. |
| SV-7 | Marge | F - 1100 | 20 | Qtr. Chestnut | 220 | Neck | 4.0 | 15.0 | Stood on stimulus. Blood taken, branded. |
| SV-10 | Duke | G - 1100 | 10-12 | Paint | 220 | Neck | 3.0 | 24.0 | Blood taken. |
| SV-11 | Bill | G - 1300 | 12 | Bay | 260 | Neck | 3.0 | 15.0 | Blood taken, branded. |
| SV-14 | Dix | F - 1050 | 15 | Blk., Wh., Socks, Blaze | 210 | Neck | 3.0 | 12.0 | Bellows used to assist breathing, branded. Blood taken. |
| SV-15 | Chester | G - 1100 | 17 | Bay | 220 | Neck | 7.0 | 13.0 | Blood taken, branded. |
| SV-16 | Marty | G - 1050 | 20 | Qtr. Chestnut | 210 | Neck | 4.0 | 9.0 | Blood taken, branded. |
| SV-17 | Casey Horse | G - 1000 | 20 | Qtr. Chestnut | 200 | Neck | 3.0 | 8.0 | Blood taken, branded. |
| SV-18 | Mouse | G - 900 | 12 | Qtr. Welsh-X | 180 | Neck | 2.0 | 6.0 | Blood taken, branded. |

| Exper. No. | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Site of Injection | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| SV-19 | Crazy Horse | F - 1050 | 14 | Qtr. Chestnut | 210 | Neck | 2.5 | 8.5 | Pumped with bellows for 1 min. Blood taken, branded. |
| SV-20 | Joe | G - 1000 | 15 | Qtr. Blk. | 200 | Shoulder | 4.0 | 14.5 | Respiratory arrest. Used bellows and gave $O_2$. Blood taken. |
| SV-21 | Blaze | G - 1100 | 15 | Qtr. Chestnut | 220 | Neck | 2.5 | 10.0 | Blood taken, branded. |
| SV-22 | Big Red | G - 1100 | 20 | Bay | 220 | Shoulder | 3.0 | 10.0 | Blood taken, branded. |
| SV-23 | Do-Do | G - 1050 | 8-9 | Qtr. Walker-X | 210 | Shoulder | 1.5 | 9.0 | Resp. distress. Used bellows. Blood taken, branded. |
| SV-25 | Smokey | G - 900 | 7 | Appy. Grey | 180 | Shoulder | 2.5 | 7.5 | Bellows used but not needed. Blood taken, branded. |
| SV-26 | Spring | F - 900 | 6-7 | Qtr./Tenn. Chestnut | 180 | Shoulder | 1.0 | 9.0 | Resp. distress. Bellows used. Blood taken, branded. |
| SV-27 | Rocky | G - 1050 | 12 | Qtr./Draft Appy. Wh. | 210 | Shoulder | 1.5 | 8.5 | Respiratory assist with bellows. Blood taken, branded. |
| SV-28 | Commanche | G - 800 | 5 | Appy. Roan | 160 | Neck | 1.5 | 12.5 | Blood taken. |
| SV-29 | Half-Hitch | G - 850 | 11 | Appy. Roan | 128 | Neck | 4.0 | 3.0 | Blood taken, branded. |
| SV-30 | Clyde | G - 900 | 12 | Appy. Blk. | 135 | Shoulder | 1.0 | 7.0 | Blood taken. Bellows used 2-3 min. |
| SV-31 | Bingo | G - 800 | 11 | Qtr. | 120 | Shoulder | 2.5 | 7.5 | Bellows for 3 min. Blood taken, branded. |
| SV-32 | Mohee | G - 900 | 15 | Appy., Red Roan | 140 | Shoulder | 3.0 | 4.0 | Blood taken, branded. |
| SV-33 | Buck-N | G - 1100 | 19 | Qtr. Buckskin | 170 | Shoulder | 5.0 | 5.0 | Blood taken, branded. |

| Exper. No. | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Site of Injection | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| SV-34 | Prince | G - 1100 | 15 | Morgan/Qtr. | 170 | Shoulder | 2.5 | 7.5 | Assist breathing with bellows and oxygen. Blood taken, branded. |
| SV-35 | Levi | G - 800 | 5 | Qtr. Brown | 120 | Shoulder | 2.0 | 10.0 | Blood taken, branded. |
| SV-36 | Chantilly | F - 800 | 5 | Qtr./Tenn. Appy. | 120 | Shoulder | 1.0 | 6.0 | Blood taken. Wound sutured, branded. |
| SV-37 | Chico | G - 1000 | 18 | Qtr. | 150 | Shoulder | 2.0 | 10.0 | Oxygen given. Blood taken, branded. |
| SV-38 | Ruby | F - 950 | 18 | Qtr./Morgan Blue Roan | 140 | Shoulder | 2.5 | 8.5 | Bellows used to assist breathing. Blood taken, branded. |
| SV-39 | Cherokee Red | G - 1000 | 12 | Qtr. Sorrel | 150 | Shoulder | 3.0 | 7.0 | Blood taken, branded. |
| SV-40 | Runt | F - 750 | 20 | Qtr./Arab. Buckskin | 110 | Shoulder | 2.5 | 5.5 | Blood taken, branded. |
| SV-41 | Fred | G - 850 | 19 | Qtr. Blk. | 230 | Shoulder | 1.5 | 12.5 | Accidental overdose. Trach tube used. Oxygen administered with respirator. Branded, blood taken. |
| MULES | | | | | | | | | |
| SV-8 | Jack | G - 1100 | 10 | Mule-Bay | 220 | Neck | 3.0 | 7.0 | No blood taken, branded. |
| SV-9 | Casey | G - 900 | 6 | Mule-Grey | 180 | Neck | 4.0 | 10.0 | No blood taken, branded. |
| SV-12 | Buck | G - 750 | 6 | Mule-Buckskin | 160<br>180 | Neck | 5.5 | 3.5 | No blood taken. On 8/29/78 this mule was dosed at 20 mg/100 lbs. and did not go down. Branded. |
| SV-13 | Molly-B | F - 900 | 7 | Mule Blk. | 180<br>200 | Neck | 4.0 | 9.0 | Respiratory assist with bellows. This mule did not go down at 20 mg/100 lb. Branded. |

| Exper. No. | Name/ No. | Sex - Wt. Lbs. | Age Yrs. | Breed Type | Dose (mg) | Site of Injection | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| SV-24 | Bobbie | F - 700 | 2 | Mule Buckskin | 140 | Neck | 1.5 | 16.5 | Mule was dosed at 700 lbs., branded. |
| SV-42 | Molly-A | F - 950 | 8-9 | Mule Blk. | 210 | Neck | 6.5 | 15.5 | Dosed for 1050 lb. mule, branded. |
| SV-43 | Riva | F - 800 | 6 | Mule Sorrel | 180 | Neck | 9.0 | 5.0 | Mule tried to resist the drug, branded. |
| SV-44 | Frankie | G - 1000 | 7 | Mule Grey | 220 | Neck | 5.5 | 26.5 | Dosed for an 1100 lb. mule. Tried to rise at 15 and 38 min. after going down, branded. |

Table 9. Immobilization Studies with Succinylcholine in Wild Horses at Pullman, WA, 4/9/79-7/19/80
(Includes Moscow, ID, Milton-Freewater, OR and Parkland, WA)

| Exper. No. | Horse No. | Date | Sex - | Wt. Lbs. | Age Yrs. | Location | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SM-30 | WSU-6 | 4/9/79 | M - | 350 | 1 | WSU | 80 | Pneudart | No effect | -- | |
| | Blk. Colt | | | | | | 100 | Pneudart | Not down | -- | Trembled at 1.5 min. |
| | | | | | | | 80 | Palm. Dart | Not down | -- | Stuck in gaskin. |
| | | | | | | | 100 | Palm. Dart | Not down | -- | Dart penetrated rump. |
| | | | | | | | 140 | Palm. Dart | 2 | 24 | Xyl.--2.5 I.V., Ket.--5.0 I.V. Bellows used. Haltered and held by hand--15 min. |
| SM-31 | WSU-7 Palamino | 4/9/79 | M - | 400<br>500 | 2 | WSU | 150 | Palm. Dart | 2 | 20 | 10% GG--275 cc. Light drop (sternum), freeze branded. |
| SM-32 | 726-WSU-4 | 4/10/79 | M - | 850 | 4 | WSU | 200 | Pneudart | No effect | -- | Flank hit. |
| | | | | | | | | Pneudart | No effect | -- | Dart flipped out. |
| | | | | | | | 240 | Pneudart | No effect | -- | Hit high on hip--flipped out. |
| | | | | | | | 240 | Pneudart | 5 | -- | |
| SM-33 | WSU-1 | 4/10/79 | M - | 900 | 7 | WSU | 240 | Pneudart | <2 | -- | Raised up in 5 min., stayed down 12 min. |
| SM-37 | WSU-1 Roan | 4/26/79 | M - | 1000 | 7 | WSU | 200 | Palm. Dart Pneudart Gun | >4 | <10 | 40% GG--80 cc I.V. Stuck under tail--castrated--up easy. |
| SM-38 | WSU-4 Sorrel | 4/26/79 | M - | 900 | 4 | WSU | 180 | Palm. Dart | 5 | <10 | 40% GG--100 cc I.V. Castrated, up easy. |
| SM-39 | WSU-3 | 4/26/79 | M - | 800 | 4 | WSU | 180 | Palm. Dart | -- | 20 | 5 Xyl. + 10 Ket., 100 GG 40%. Unsteady for 30-40 min. (peroneal n. dam). Castrated--high flanker. |

| Exper. No. | Horse No. | Date | Sex - Wt. Lbs. | Age Yrs. | Location | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SM-40 | WSU-2 | 4/26/79 | M - 1000 | 7 | WSU | 210 | Palm. Dart | -- | 25 | 6 Xyl. + 18 Ket (9 + 9). Long, stormy recovery--castrated. |
| SM-41 | WSU-5 | 4/26/79 | M - 800 | 4 | WSU | 200 | Palm. Dart | -- | 40 | Surital (1 gm + 2 gm) + 1 Xyl. Slow recovery, not stormy--castrated. |
| SM-42 | 711 | 5/7/79 | M - 500 | 1 | Moscow | 125 | I.M. Neck Syringe | <2 | 12 | 10% GG--150 cc. Shallow resp., bellows used--castrated--on sternum in 10 min. |
| SM-43 | 903 | 5/7/79 | M - 450 | 1 | Moscow | 125 | I.M. Neck Syringe | <3 | 45 | 10% GG--500 cc. Castrated--high flanker (20 min. to extract). |
| SM-44 | 664 | 5/7/79 | F - 300 | 1 | Moscow | 75 | I.M. Neck Syringe | 2 | 10 | Excised small fibroid--Rt. shoulder. |
| SM-49 | Sorrel | 6/28/79 | M - 850 | 5 | WSU | 200 | Dart-Femoral Muscle | None | -- | |
| | | | | | | 250 | Dart | 3 | 40 | 40% GG--100 cc I.V., 4 cc Ace I.M. Respir. distress, bellows used for total of 7 min. |
| SM-50 | Brown | 6/29/79 | M - 400 | 1 | WSU | 100 | Dart | 2 | 5 | 2 cc Ace. I.M. Respir. distress. |
| SM-51 | Billy Bronc | 6/29/79 | M - 950 | 5 | WSU | 250 | Dart | 1.75 | 4 | 50 cc 40% GG I.V., 4 cc Ace. I.M. Violent reaction when trying to sideline horse. |
| | | | | | | 200 | Syringe | -- | -- | Second dose of sucostrin had greater effect when administered after GG. |

| Exper. No. | Horse No. | Date | Sex | Wt. Lbs. | Age Yrs. | Location | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SM-52 | | 12/7/79 | F | | | Milton-Freewater, Oregon | | Dart-Range | -- | -- | I.M. Adopted horse--escaped. |
| SM-53 | | 4/7/80 | F | | | Parkland, Washington | 400 | Dart-Range | -- | -- | 40% GG I.V., 5 cc Xylazine I.M. Bellows used. |
| SM-54 | Broomtail | 4/15/80 | M | | | WSU | 200 | Dart-Corral | 3 | 32 | 150 cc 40% GG I.V., 5 cc Xylazine I.M. Horse struggled much and got up twice. Thrown with ropes and castrated. |
| SM-55 | 392 | 4/15/80 | M | | | WSU | 175 | Dart-Corral | 2 | 20 | 100 cc 40% GG I.V., 5 cc Xylazine I.M. Castrated. |
| SM-56 | | 5/2/80 | M | | | WSU | 200 | Dart-Corral | 4 | 10 | 100 cc 40% GG I.V. Castrated. |
| SM-57 | | 5/8/80 | M - | 800 | 2 | WSU | 180 | Dart-Corral | 4 | 15 | 100 cc 40% GG I.V. Castrated. |
| SM-58 | | 5/8/80 | M - | 800 | 2 | WSU | 180 | Dart-Corral | 3 | -- | 100 cc 40% GG I.V. Resuscitation given for 3 min. Castrated. |
| SM-59 | | 6/11/80 | F - | 400 | 1 | WSU | 100 | Dart-Corral | 8 | ≈32 | 4.0 cc 10% Gallamine. Down and up twice. This horse was accidentally darted with 4.0 cc Gallamine. |
| SM-60 | | 7/15/80 | G - | 900 | 2 | WSU | 200<br>225 | Dart-Corral | -- | -- | |
| | | | | | | | 270 | | 1.5 | 5.5 | Good recovery. |
| | | 7/19/80 | G - | 900 | 2 | WSU | | | | | Horse found dead 7/19/80. |
| SG-1-97 | | 7/18/79-9/20/79 | 7 Geldings | | | WSU | | Darts | | | Special study--LVG thesis. |

Table 10. Immobilization Studies with Succinylcholine Chloride in Wild Horses at Burns, Oregon (1/3/79-7/29/80)

| Exper. No. | Horse No. | Date | Sex | Wt. Lbs. | Age Yrs. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SM-1 | V537 | 1/3/79 | F | 900 | -- | 180 | Dart | -- | -- | Dart in inner thigh--no effect; given 2nd dose 10 min. after 1st dose. |
|  | V537 | 1/3/79 | F | 900 | -- | 200 | Dart | 2 | 12 | Shallow respiration on 2nd dose, icy ground prevented horse from standing sooner. |
| SM-2 | V538 | 1/3/79 | M | 1000 | 11 | 200 | Dart | 1 | 15 | Dart in rump, resp. arrest, used bellows for a few min. |
| SM-3 | 873 | 2/26/79 | F | 350 | 2 | 60 | Syringe-I.M. | 2.5 | 5 | Dosed with syringe in chute, freeze-branded while down. |
| SM-4 | 871 | 2/26/79 | M | 300 | 1 | 50 | Syringe-I.M. | 2 | 5 | Dosed with syringe in chute, freeze-branded while down. |
| SM-5 | 872 | 2/26/79 | M | 300 | 1/2 | 40 | Syringe-I.M. | 1.8 | 4 | Dosed with syringe in chute, freeze-branded while down. |
| SM-6 | 873 | 2/26/79 | M | 300 | 1/2 | 40 | Syringe-I.M. | Not down | -- | Didn't go down. |
| SM-7 | 897 | 2/26/79 | M | 400 |  | 80 | Syringe-I.M. | 2 | 5 | Acepromazine. Slower to stand, allowed close approach and petting after standing. |
| SM-8 | 515 | 2/28/79 | M | 1000 | 5 | 200 | Dart | 3 | 4 | Acepromazine. Docile but not tame, easily loaded into pickup truck. |
| SM-9 | 680 | 2/28/79 | M | 900 | 2 | 180 | Dart | 1.5 | 8 | Acepromazine. Very docile, could be petted. |

| Exper. No. | Horse No. | Date | Sex | Wt. Lbs. | Age Yrs. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SM-10 | V537 | 2/28/79 | F | 900 |  | 500 | Dart | <1 | -- | For euthanasia, 3 small respiratory attempts, never moved. |
| SM-11 | 772 | 2/28/79 | M | 400 |  | 80 | Syringe-I.M. | 1.7 | 6 | Shallow resp., examined hock (previously injured) while down, no treatment. |
| SM-12 | 610 | 2/28/79 | F | 900 | 3 | 180 | Dart | 4 | -- | 5 gr. morphine in 5 cc 10% xylazine. Some sedation but not sufficient to handle. |
| SM-13 | 618 | 2/28/79 | F | 850 | 5 | 170 | Dart | No effect | -- | Dart in hind quarters, dose between muscles(?). |
|  | 618 | 2/28/79 | F | 850 | 5 | 170 | Dart | 2 | -- | 5 gr. morphine in 5 cc 10% xylazine. Stood within 1 min. of morphine/xylazine injection. |
| SM-14 | 564 | 2/28/79 | F | 1000 | 12 | 200 | Dart | 1.5 | -- | 9.75 gr. morphine, 5 cc xylazine. Shallow resp. Stood within 1 min. of morphine/xylazine injection, some incoordination. |
| SM-15 | 898 | 2/28/79 | M | 400 | 8 mo. | 80 | Syringe-I.M. | 1.5 | -- | Acepromazine. Shallow for 2 min., calm and wobbly when stood up. |
| SM-16 |  | 2/28/79 | F | 900 | 15 | 180 | Dart | 3 | 5 | Acepromazine. Pregnant and in poor condition, handled easily but fell twice fighting rope. |
| SM-17 | 902 | 2/28/79 | M | 400 | 8 mo. | 80 | Syringe-I.M. | 2 | 5 | 1 cc 2% curare. Very calm and tractable. |

| Exper. No. | Horse No. | Date | Sex | Wt. Lbs. | Age Yrs. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SM-18 | 152 | 3/1/79 | | 1100 | 12 | 220 | Dart | 4 | 15 | 2 cc 2% curare. Some thrashing with hind legs while down. Tried to rise at 9 min. |
| SM-19 | 750 | 3/1/79 | M | 750 | 3 | 190 | Dart | 1.5 | 5 | 1% Acepromazine. Bellows for 2 min., allowed petting after standing. |
| SM-20 | 917 | 3/1/79 | F | 1000 | | 200 | Dart | Down | -- | 3-Ace, 1.5-10% curare. OK with some tranquilizing. |
| SM-21 | | 3/1/79 | M | 1000 | 5 | 200 | Dart | 2 | -- | Ace, xylazine. |
| SM-22 | | 3/1/79 | M | 650 | 2 | 100 | Syringe | Not down | -- | Able to separate it from herd. |
| SM-23 | | 3/1/79 | F | 850 | | 500 | Syringe | 2 | -- | For euthanasia. |
| SM-24 | 911 | 3/1/79 | F | 900 | 2 | 180 | Syringe | 2 | 45 | GG-10%. Sternal recumb. last 10 min. |
| SM-25 | WSU-1 Roan | 3/30/79 | M | 900 | 7 | 200 | Palm. Dart | 2 | 20 | 10% GG, Ace. 3 men led, hauled to Pullman. |
| SM-26 | WSU-2 Black | 3/30/79 | M | 1000 | 7 | 190 | Dart | Not down | -- | Hit in tendon above hock--staggered--waited 7 min. |
| | WSU-2 Black | 3/30/79 | M | 1000 | 7 | 200 | Dart | 2 | 8 | Xyl., Ace. Bellows, 2 min. Led with some difficulty--hauled to Pullman. |
| SM-27 | WSU-3 Sorrel | 3/30/79 | M | 800 | 4 | 200 | Dart | 2 | 4 | Xyl.-5 cc I.V., Morph.-5 gr. Up immed. after morph., difficult to lead, hauled to Pullman. |

| Exper. No. | Horse No. | Date | Sex | Wt. Lbs. | Age Yrs. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SM-28 | WSU-4 Sorrel | 2/20/79 | M | 850 | 4 | 200 | Dart | Not down | -- | Good hit (?) waited 10 min. |
| | | | | | | 200 | Dart | 2 | 7 | Xyl.-5 I.V., Ace.-2 I.V.. 4 I.M. Hazed OK, hauled to Pullman. |
| SM-29 | WSU-5 Sorrel | 3/30/79 | M | 800 | 4 | 200 | Dart | 2 | 5 | Xyl.-4 I.V., Ace.-2 I.V., 4 I.M. Hazed OK, hauled to Pullman. |
| SB-1-7 | | 11/8/79 | 4 M<br>3 F | | 3-20 | 250-300 | Helicopter-Dart | 1.0 $(\bar{y})$ | 45.57 $(\bar{y})$ | GG 100 cc I.V., Ace. 5 cc I.M. Three required bellows due to respiratory difficulties. |
| SB-8 | 394 | 11/9/79 | M | | 3 | 250 | Dart-Corral | 1.0 | 30.0 | GG 100 cc I.V., ketamine 10 cc, rompun 5 cc I.M. Put horse down to see if dart was buried in muscle from 11-8-79 dart (not found). |
| SB-9-33 | | 11/9/79<br>11/10/79 | 14 Stallions<br>11 Mares | | 2-20 | 175-300 | Syringe-Chute | 2.05 $(\bar{y})$ | 10.42 $(\bar{y})$ | 25 blood samples. Horses were also freeze branded. Bellows needed for 3 horses. |
| SB-34-40 | | 11/10/79 | 4 Colts<br>3 Fillies | | 8 wks.-5 mo. | 50-150 | Syringe-Chute | 1.5 $(\bar{y})$ | 6.41 $(\bar{y})$ | Freeze branded. Resuscitation required for 2 horses. 5 blood samples (horse broke some tubes). |
| SB-41-46 | | 11/10/79 | 5 Colts<br>1 Filly | | 5 mo.-1 yr. | 80-125 | Syringe-Chute | 1.79 $(\bar{y})$ | 7.2 $(\bar{y})$ | Vale horses were generally in poorer condition than Burns horses. 4 horses needed resuscitation. Blood taken from all 6. |

| Exper. No. | Horse No. | Date | Sex | Wt. Lbs. | Age Yrs. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SB1-46 | | | | | | | | 1.749<br>($\bar{y}$) | 9.17<br>($\bar{y}$) | |
| SB-47-50 | | 11/12/79 | 3 Stallions<br>1 Mare | | | | Helicopter-Dart | -- | -- | These were 4 lead horses that could not be trapped. |
| SB-51-70 | | 11/13/79 | 20 Colts | | <1 | | Syringe-Chute | -- | -- | All colts were less than 1 yr. of age. |
| SB-71-73 | | 11/14/79 | 3 Stallions | | | | Helicopter-Dart | -- | -- | Euthanized these 3 old stallions. |
| SB-74-79 | | 11/14/79 | 6 Horses | | | | Helicopter-Dart | -- | -- | 3 pairs were darted. 1 mare died of broken neck. Pair #2 used GG and Ace. Pair #3 increased dose from 25 mg/100 lb. to 30 mg/100 lb. for second drop. |
| SB-80-89 | | 11/15/79 | 10 Horses | | | | Helicopter-Dart | -- | -- | 2 old stallions euthanized. 1 8 yr. old stallion died (100 cc GG given too soon after breathing established). |
| SB-90-94 | | 11/16/79 | 5 Horses | | | | Helicopter-Dart | -- | -- | 1 9 yr. 1100 lb. stallion died (two darts in rapid succession). |
| SB-101 | | 7/21/80 | M | 1000 | | 250<br>300 | Helicopter-Dart | 2+ | -- | Good hit with first dart, but no effect was observed. Horse recovered and ran off before could be reached. |
| SB-102 | | 7/21/80 | F | 900 | | 250<br>250 | Helicopter-Dart | 1 | Dead | Respiratory arrest with shock. Resuscitation did not revive horse. |

| Exper. No. | Horse No. | Date | Sex | Wt. Lbs. | Age Yrs. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SB-103 | | 7/21/80 | M | 600 | 1 | 150<br>175 | Helicopter-Dart | 1 | -- | 50 cc GG, 2 cc Ace. No bellows necessary. Blood taken for tests. First dart in flank did not put horse down. |
| SB-104 | | 7/22/80 | M | 900 | 4 | 300 | Helicopter-Dart | 1 | Dead | Bellows used 10 min. Gums were grey when reached, then turned white. No pulse. |
| SB-105 | | 7/22/80 | F | 700 | 3 | 200 | Helicopter-Dart | 2 | -- | 50 cc GG, 1+ cc Ace. Pumped before and after GG was given. Horse was hobbled and branded. |
| SB-106 | | 7/22/80 | F | 600 | 3 | 175 | Helicopter-Dart | 5 | -- | 45 cc GG, 1 cc Ace. Blood collected. |
| SB-107 | | 7/22/80 | M | 550 | 2 | 150<br>175 | Helicopter-Dart | 1 | -- | 50 cc GG, 2 cc Ace. Blood collected. |
| SB-108 | | 7/22/80 | M | 600 | 2 | 175<br>175 | Helicopter-Dart | 1.5 | -- | 50 cc GG, 2 cc Ace. Blood collected. |
| SB-109 | | 7/23/80 | M | 1400 | 12 | 325 | Helicopter-Dart | 1 | 25 | 135 cc GG, 5 cc Ace. Pumped air for a few minutes. |
| SB-110 | | 7/23/80 | F | 1200 | 14 | 300 | Helicopter-Dart | 2 | 27 | 100 cc GG, 5 cc Ace. No resuscitation necessary. |
| SB-111 | | 7/23/80 | M | 1000 | 9 | 300 | Helicopter-Dart | 1 | -- | 100 cc GG, 5 cc Ace. Blood collected, pumped air for 2 min. |
| SB-112 | | 7/23/80 | F | 1100 | 10 | 300 | Helicopter-Dart | -- | -- | 100 cc GG, 5 cc Ace. No blood samples. |

| Exper. No. | Horse No. | Date | Sex | Wt. Lbs. | Age Yrs. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| SB-113 | | 7/23/80 | M | 300 | 3 mo. | 75<br>100<br>140 | Helicopter-Dart | 2 | -- | Pumped a few min. Blood collected. |
| SB-114 | | 7/23/80 | F | 1100 | 10 | 300<br>300 | Helicopter Dart | 2 | 10 | 100 cc GG, 5 cc Ace. Collected blood. |

Table 11. Immobilization Studies with Succinylcholine in Wild Horses at Prineville, Oregon (4/17/79-6/26/79)

| Exper. No. | Date | Horse No. | Sex - Wt. Lbs. | Age Yrs. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| SM-34 | 4/17/79 | | M | 1 | 260 | Pneudart | No Effect? | | Good hit--20 yds., colt lost, seen next day. |
| SM-35 | 4/17/79 | | M | 2 | 260 | Pneudart | No Effect? | | Good hit--stuck well. |
| SM-36 | 4/19/79 | | F | | 200 | Palmer Dart | Down | <10 | Up and gone before reached--with colt. |
| SM-45 | 5/15/79 | 2 Blacks | M - 1000<br>F - 800 | ?<br>? | 200<br>200 | Palmer Dart<br>Palmer Dart | Not Down<br>Not Down | | 1 dart in left shoulder.<br>1 dart hit rear leg--stuck? |
| SM-46 | 5/15/79 | Band of 4 | | | 200 | Palmer Dart | Not Down | | 3 darts fired--none hit? Poor position, too fast. |
| SM-47 | 5/16/79 | Grey | M - 800 | 2 | 200 | Palmer Dart | Not Down | | 2 darts fired--1 miss, 1 near hit--needle bent, barb off. |
| SM-48 | 5/17/79 | Grey | M - 800 | 2 | 250 | Dart-Neck | 2 min. | 45 | Cyanotic, bellows used. Led 1.5 hrs. with halter and 2 ropes. 100 cc of 40% GG and 5 cc Ace Promazine used. |

Table 12. Immobilization Studies with Succinylcholine Cl in Wild Horses
at Burns Junction and Owyhee River Breaks, OR
(11/27/79-11/29/79)

| Exper. No. | Date | Number of Horses Darted | Sex - Wt. Lbs. | Age Yrs. | Dose (mg) | Method | Induc. Time (min.) | Recov. Time (min.) | Comments: In Support of Squaw Butte Experiment Station Study Involving Radio Transmitters |
|---|---|---|---|---|---|---|---|---|---|
| SBJ 1-14 | 11/27/79-<br>11/28/79 | 14 horses darted.<br>(1 death) | | | | Helicopter-Dart | | | Began to dart horses at 25 mg/100 lbs. and later reduced dose to 22 mg/100 lbs. 13 horses were collared and released. One 20 yr. old male died (possible overdose). |
| SBJ 15-22 | 11/28/79 | 8 horses darted.<br>(3 deaths) | F - 800 | 4 | 230<br>200 | Helicopter-Dart | | Died | Five minutes between darts. Resuscitation didn't revive horse. |
| | | | F - 600 | | 200 | Helicopter-Dart | 5 sec. | Died | Possible internal injury from fall after darted. |
| | | | M - 900 | 4 | 230 | Helicopter-Dart | | Died | Horse was run hard on steep terrain. Possible shock. The ambient temperature was 10°F. The terrain was steep and rugged. These horses were very wild. Five horses were radio collared and released. |
| SBJ 23-29 | 11/29/79 | 7 horses darted.<br>(1 death) | F - 900 | | 200<br>200 | Helicopter-Dart | | Died | Horse ran 400 yards, climbed a steep ridge and dropped. Attempts to resuscitate failed. Air came out of mouth when bellows were used. 6 horses were radio collared and released, including one that was resuscitated. |
| | | | | | | | | | Horses that died in the SBJ group might have gone through a shock syndrome of sorts. Factors which could have contributed to this shock were cold temperature, steep rugged terrain, highly spirited and excitable horses, hard falls, and harassment from the helicopter. |

## Table 13. Immobilization of Wild Horses with Succinylcholine Cl at Challis and Salmon, Idaho

| Exper. No. | Date | Sex - Wt. Lbs. | Age Yrs. | Dose (mg) | Method | Comments |
|---|---|---|---|---|---|---|
| SC-1 | 10/3/79 | F - 700 | | 300 | Helicopter Dart | 40 cc euth. soln. Wobbler disease. |
| SC-2 | 10/3/79 | M - 1100 | | 300 | Ground Dart | 50 cc euth. soln. Senile. |
| SC-3 | 10/3/79 | F - 400 | Foal | ≈100 | Helicopter Dart | Escaped from truck en route to Salmon. Apnea for approximately one min. |
| SC-7 | 10/4/79 | F - 1100 | 6 | 300 | Ground Dart | 50 cc euth. soln. Wet mare with broken neck. |
| SA000-148 | 10/6/79-<br>10/9/79 | 18 colts<br>19 fillies<br>72 mares<br>40 stallions | 2- 6 mo.<br>2- 6 mo.<br>1-30 yr.<br>1- 9 yr. | | | This group not immobilized (except for 2) but blood collected, freeze branded, etc., while in fly chute. |
| SA-032 | 10/6/79 | M | 9 | | Ground Dart | Horse tangled in fence. Blood samples taken. |
| SA-057 | 10/9/79 | F | 30 | | Pole Syringe | Blind mare. Blood samples taken and freeze branded. |
| SK-1-24 | 12/16/79-<br>12/19/79 | 23 stallions<br>1 mare | 1-20 yr. | | Helicopter Dart | These immobilizations done in support of Eastern Montana College study involving anti-fertility drugs in stallions. |
| | | M | 7 | | Helicopter Dart | 10 stallions immobilized, injected with anti-fertility drug and released. |
| | | M | 8 | | | |
| | | M | 7 | | | |
| | | M | 15 | | | |
| | | M | -- | | | |
| | | M | 10 | | | |
| | | M | 8 | | | |
| | | M | 18+ | | | |
| | | M | 5 | | | |
| | | M | 8 | | | |

| Exper. No. | Date | Sex - Wt. Lbs. | Age Yrs. | Dose (mg) | Method | Comments |
|---|---|---|---|---|---|---|
| | | M | | | Helicopter Dart | 3 stallions immobilized, but recovered and ran off before restraints applied. |
| | | M | | | | |
| | | M | | | | |
| | | M | | | | Immobilized, but couldn't land or observe recovery. |
| | | F | | | | Mare immobilized by mistake, released. |
| | | M | 13+ | | Helicopter Dart | Died, two doses within 10 min. Resus. failed. |
| | | M | 11 | | | Died, stressed by chase from helicopter. |
| | | M | -- | | | Died, possible overdose of sucostrin. |
| | | M | 4 | | | Died, broken neck resulted from fall after darted. |
| | | M | 20+ | | | Died, stressed by prolonged chase, possible "shock syndrome." |
| | | M | 20+ | | | Died, 3 doses and prolonged chase. |
| | | M | 3 | | | Died, slid 75 yards after dart. Unable to ventilate in time. |
| | | M | 1+ | | | Died, overdose due to misidentification of horse. |
| | | M | -- | | | Died, shock syndrome. |

Table 14. Serum Enzymes in Normal and Succinylcholine Immobilized Domestic and Wild Horses
Values shown are means ($\bar{y}$) and 95% confidence intervals (CI)

| Experimental Group | Number of Horses | CPK $\bar{y}$ | CPK 95% CI | LDH $\bar{y}$ | LDH 95% CI | SGOT $\bar{y}$ | SGOT 95% CI | pCHE $\bar{y}$ | pCHE 95% CI |
|---|---|---|---|---|---|---|---|---|---|
| Domestic Rested Controls | 12 | 40.3 | 29.27 -- 51.40 | 255.6 | 221.3 -- 289.9 | 241.7 | 209.0 -- 274.3 | 50.25 | 34.5 -- 66.0 |
| Domestic Rested Succ. Cl. (Down)(SGB) | 5 | 43.0 | 39.60 -- 46.40 | 256.8 | 171.4 -- 342.2 | 219.0 | 183.7 -- 254.3 | 17.21 | 14.8 -- 19.6 |
| Domestic Rested Succ. Cl. (1 hr.)(SGB) | 5 | 56.0 | 35.70 -- 76.30 | 249.6 | 162.9 -- 336.3 | 212.8 | 177.1 -- 248.5 | 10.20 | 8.4 -- 12.0 |
| Domestic Exercised Control (SGB) | 5 | 72.4 | 16.93 -- 127.97 | 282.4 | 191.6 -- 373.2 | 267.8 | 129.6 -- 406.0 | 63.80 | 47.5 -- 80.1 |
| Domestic Exercised Succ. Cl. (Down) (SGB) | 4 | 40.5 | 20.50 -- 60.50 | 291.5 | 162.4 -- 420.6 | 287.0 | 79.2 -- 494.8 | 63.30 | 44.6 -- 81.9 |
| Utility Control (SV) | 19 | 51.9 | 42.20 -- 61.60 | 278.7 | 244.7 -- 312.6 | 273.2 | 239.9 -- 306.4 | -- | -- -- -- |
| Utility Succ. Cl. (1 hr.)(SV) | 19 | 102.2 | 72.00 -- 132.30 | 302.8 | 264.0 -- 341.7 | 261.7 | 222.7 -- 300.6 | -- | -- -- -- |
| Wild Succ. Cl.-Dart (SG) | 7 | 41.4 | 30.20 -- 52.70 | 387.4 | 303.1 -- 471.8 | 235.3 | 192.1 -- 278.5 | 85.50 | 75.0 -- 96.0 |
| Wild Succ. Cl.- Syringe (SB) | 28-36 | 708.7 | 173.30 -- 1244.20 | 1099.4 | 777.1 -- 1421.6 | 818.9 | 590.3 -- 1047.5 | 13.10 | 11.0 -- 15.1 |
| Wild Succ. Cl.- Helicopter (SBJ) | 12-14 | 151.6 | 10.00 -- 293.10 | 417.6 | 352.5 -- 482.6 | 345.9 | 180.6 -- 511.3 | 21.90 | 15.8 -- 28.0 |

| Experimental Group | Number of Horses | CPK |  |  | LDH |  |  | SGOT |  |  | pCHE |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | $\bar{y}$ |  |  | $\bar{y}$ |  |  | $\bar{y}$ |  |  | $\bar{y}$ |  |
|  |  | ← | 95% CI | → | ← | 95% CI | → | ← | 95% CI | → | ← | 95% CI | → |
| Wild Succ. Cl.-<br>Helicopter (SK) | 3 | -- | --<br>-- | -- | 288.1 | 481.3<br>-- | 674.6 | 186.3 | 301.3<br>-- | 416.3 | -- | --<br>-- | -- |
| Wild Physical<br>Restraint (SA) | 59-61 | 124.30 | 149.1<br>-- | 173.40 | 352.5 | 651.3<br>-- | 482.6 | 375.8 | 418.0<br>-- | 460.2 | 14.2 | 18.60<br>-- | 23.0 |
| Wild Succ. Cl.-<br>Helicopter (SB) | 9 | -21.30 | 214.0<br>-- | 449.30 | 703.6 | 734.9<br>-- | 766.2 | 359.2 | 393.4<br>-- | 427.7 | 3.5 | 6.80<br>-- | 10.1 |

Table 15. Serum Cortisol and Catecholamines in Normal and Succinylcholine Immobilized Domestic and Wild Horses
Values shown are means ($\bar{y}$) and 95% confidence intervals (CI)

| Experimental Group | Number of Horses | Cortisol | | | Catecholamines | | |
|---|---|---|---|---|---|---|---|
| | | ← | $\bar{y}$<br>95% CI | → | ← | $\bar{y}$<br>95% CI | → |
| Domestic Rested Controls | 12 | 5.96 | 7.53<br>-- | 9.10 | 411.33 | 505.16<br>-- | 593.98 |
| Domestic Rested Succ. Cl. (Down)(SGB) | 5 | 4.66 | 7.96<br>-- | 11.26 | 582.70 | 1156.99<br>-- | 1731.28 |
| Domestic Rested Succ. Cl. (1 hr.)(SGB) | 5 | 5.38 | 8.32<br>-- | 11.26 | 447.30 | 636.60<br>-- | 825.90 |
| Domestic Exercised Control (SGB) | 5 | -- | --<br>-- | -- | -- | --<br>-- | -- |
| Domestic Exercised Succ. Cl. (Down)(SGB) | 4 | 4.27 | 7.68<br>-- | 11.08 | -1119.70 | 1325.15<br>-- | 3770.04 |
| Utility Control (SV) | 31 | 2.03 | 2.45<br>-- | 2.87 | -- | --<br>-- | -- |
| Utility Succ. Cl. (SV) (1 hr.) | 31 | 4.77 | 5.60<br>-- | 6.42 | -- | --<br>-- | -- |
| Wild Succ. Cl.-Dart (SG) | 7 | 5.28 | 6.90<br>-- | 8.52 | 627.98 | 1641.64<br>-- | 2655.30 |
| Wild Succ. Cl.-Syringe (SB) | 28-36 | 9.37 | 10.50<br>-- | 11.63 | 1087.90 | 1543.10<br>-- | 1998.30 |
| Wild Succ. Cl.-Helicopter (SBJ) | 12-14 | 7.35 | 8.83<br>-- | 10.30 | -- | --<br>-- | -- |
| Wild Succ. Cl.-Helicopter (SK) | 3 | -- | --<br>-- | -- | -- | --<br>-- | -- |

| Experimental Group | Number of Horses | Cortisol $\bar{y}$ | Cortisol 95% CI | Catecholamines $\bar{y}$ | Catecholamines 95% CI |
|---|---|---|---|---|---|
| Wild Physical Restraint | 129, 19 | 6.30 | 5.84 -- 6.77 | 1113.20 | 416.17 -- 1810.24 |
| Wild Succ. Cl.-Helicopter (SB) | 9 | 8.52 | 7.18 -- 9.87 | -- | -- -- -- |

Table 16. Serum Enzymes and Cortisol in Normal and Etorphine (M-99) Immobilized Domestic Horses

Values shown are means ($\bar{y}$) and 95% confidence intervals (CI)

| Experimental Group | Number of Horses | CPK $\bar{y}$ | CPK 95% CI | LDH $\bar{y}$ | LDH 95% CI | SGOT $\bar{y}$ | SGOT 95% CI | Cortisol $\bar{y}$ | Cortisol 95% CI |
|---|---|---|---|---|---|---|---|---|---|
| Etorphine (E) T = 0 | 6 | 69.00 | 39.68 -- 98.32 | 313.67 | 223.74 -- 403.60 | 267.50 | 83.57 -- 451.43 | 5.67 | 2.79 -- 8.55 |
| Etorphine (E) T = Down | 6 | 75.33 | 49.87 -- 100.80 | 381.67 | 298.88 -- 464.46 | 278.33 | 35.66 -- 521.01 | 8.27 | 5.80 -- 10.74 |
| Etorphine (E) T = 1 hr. | 6 | 144.17 | 105.34 -- 183.00 | 336.50 | 273.77 -- 399.23 | 273.17 | 100.94 -- 446.00 | 9.25 | 6.51 -- 11.99 |
| Etorphine (E) T = 2 hr. | 4 | 253.75 | 211.15 -- 296.35 | 328.75 | 243.49 -- 414.01 | 306.25 | 199.42 -- 413.08 | 10.35 | 4.01 -- 16.70 |
| Etorphine (E) T = 24 hr. | 6 | 418.17 | 109.03 -- 727.30 | 560.67 | 391.65 -- 729.68 | 466.33 | 400.77 -- 531.90 | 3.52 | 1.94 -- 5.10 |

Table 17. Summary of Immobilization Studies with Domestic Horses
Pullman, WA (6/8/78-9/10/80)

| | | | Number of Experiments Completed | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | Date First Exper. | Age at First Exper. (Yrs.) | Gallamine (G1-29) | Succinyl Choline (S1-67) ($SGB_1$) | Etorphine (E1-6) | Curare (C1-29) | Decamethonium (D1-2) | Ketamine + Xylazine (KX1-8) | Morphine + Xylazine (MX1-12) | Total Per Horse |
| Apaca | 6/8/78 | 8 | -- | -- | -- | -- | -- | 4 | -- | 4 |
| Big Knee | 6/8/78 | 9 | 4 | 13 | -- | 6 | 1 | 4 | -- | 27 |
| Crackin Ice | 6/8/78 | 2 | 2 | 2 | -- | -- | -- | 4 | -- | 8 |
| Desert Bunny | 6/8/78 | 10 | 3 | 12 | 2 | 6 | -- | -- | 4 | 26 |
| Super | 6/8/78 | 7 | 5 | 11 | -- | 3 | -- | -- | 4 | 23 |
| Cas | 6/29/78 | 15 | 4 | 9 | -- | -- | -- | -- | -- | 13 |
| Jaded Madam | 7/6/78 | 18 | 2 | 7 | -- | 1 | -- | -- | -- | 10 |
| Ladies Man | 7/24/78 | 3 | 1 | 3 | -- | 7 | -- | -- | -- | 11 |
| Tina | 8/9/78 | 3 | -- | -- | -- | 3 | -- | -- | -- | 3 |
| Tuffy | 11/20/78 | 6 | -- | 8 | 1 | 3 | 1 | -- | -- | 12 |
| Ms. Swabe | 11/22/78 | 4 | -- | 1 | -- | -- | -- | -- | -- | 1 |
| White Mare | 3/21/79 | 10 | -- | 3 | -- | -- | -- | -- | -- | 3 |
| Bay Filly | 3/23/79 | -- | -- | 1 | -- | -- | -- | -- | -- | 1 |
| Black Coal | 7/19/79 | 6 | -- | 4 | 2 | -- | -- | -- | -- | 5 |
| Bullwinkle | 7/19/79 | 2 | -- | 3 | 1 | -- | -- | -- | -- | 3 |
| Totals | | | 21 | 77 | 6 | 29 | 2 | 12 | 8 | 150 |

Table 18. Summary of Immobilization Studies (Other Than Succinylcholine) in Domestic and Wild Horses

| Experimental Drugs | Total Exper. | Experiments Code | Experiments Numbers | Dates | Location | Horse Type | Method | Comments |
|---|---|---|---|---|---|---|---|---|
| Ketamine + Xylazine | 8 | KX | 1-8 | 6/8/78-6/10/78 | Pullman | Domes. | Syringe-I.M. | Not useful by I.M. injection. |
| Morphine + Xylazine | 12 | MX | 1-12 | 6/8/78-6/10/78 | Pullman | Domes. | Syringe-I.M. | Not useful by I.M. injection, 1 horse dead from adverse effect. |
| d-tubocurarine | 29 | C | 1-29 | 8/9/78-2/20/79 | Pullman | Domes. | Syringe-12 I.V., 17 I.M. | Not reliable. |
|  | 2 | CM | 1-2 | 3/2/79 | Burns | Wild | Syringe-I.M. |  |
| Decamethonium (C-10) | 2 | D | 1-2 | 8/21/80 | Pullman | Domes. | Syringe-I.V., I.M. | Adverse effects. |
| Etorphine (M-99) | 6 | E | 1-6 | 4/3/80-9/10/80 | Pullman | Domes. | Syringe-I.M. | Antagonized with diprenorphine, nalorphine or naloxone. Not tested in unrestrained horses. |
| Gallamine | 29 | G | 1-21 | 6/22/78-8/8/78 | Pullman | Domes. | Syringe-I.M. | Not reliable as primary capture drug. May have use in training. |
|  |  |  | 22-29 | 6/11/80-8/20/80 | Pullman | Wild | Dart |  |
| Total Experiments | 88 |  |  |  |  |  |  |  |

Table 19. Summary of Immobilization Studies with Succinylcholine in Domestic and Wild Horses

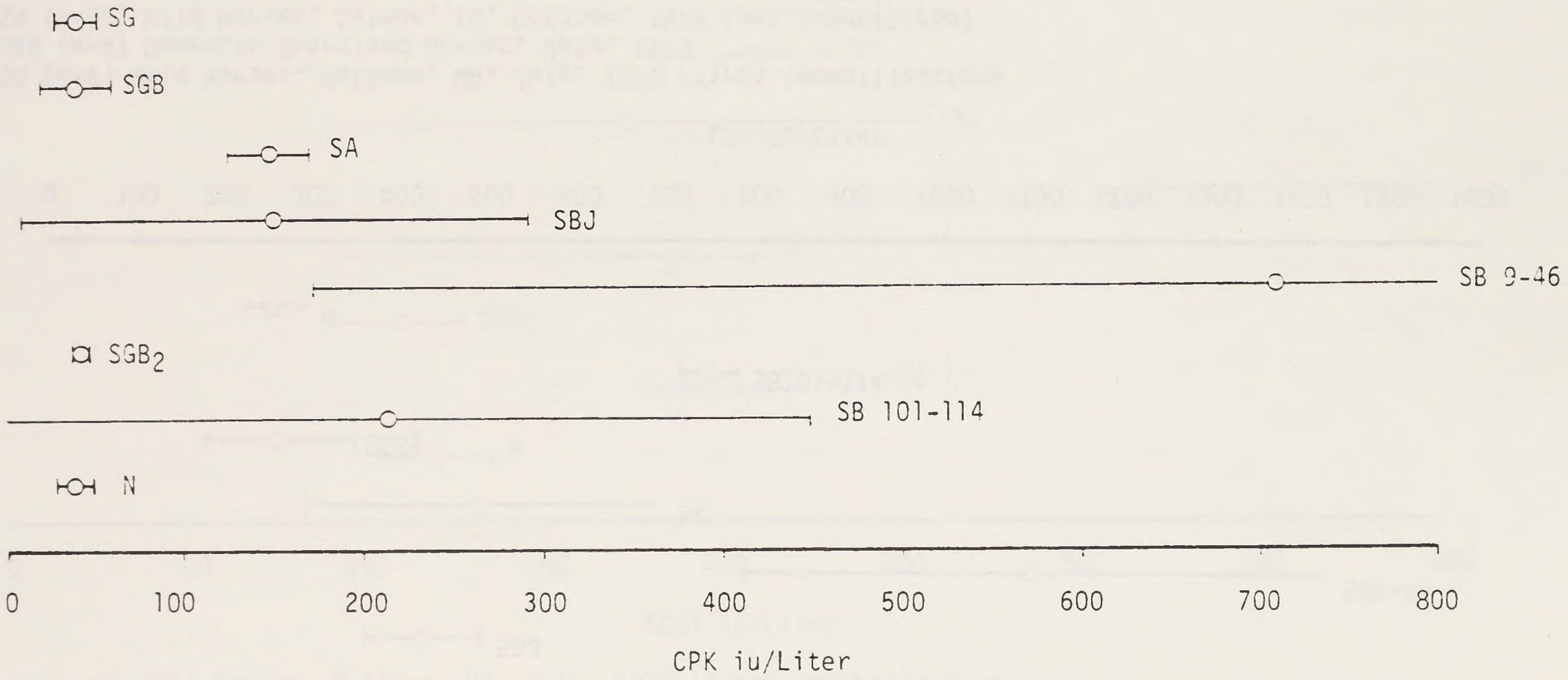
| Experimental Drug | Total Exper. | Code | Numbers | Dates | Location | Horse Type | Method | Comments |
|---|---|---|---|---|---|---|---|---|
| Succinylcholine | 67 | S | 1-61,67 | 6/29/78-<br>6/11/80 | Pullman | Domes. | Syringe - 44<br>Dart - 18 | |
| | | | 62-66 | 5/23/79 | LaCrosse | | Dart - 5 | Unapproachable horses, semi-confined in large pasture. |
| | 60 | SM | 1-29 | 1/3/79-<br>3/30/79 | Burns | Wild | Syringe - 11 I.M.<br>Dart - 18 | BLM corrals. |
| | | | 30-33 | 4/9/79 | Pullman | Wild | Dart - 4 | |
| | | | 37-41 | 4/26/79 | Pullman | Wild | Dart - 5 | |
| | | | 42-44 | 5/7/79 | Moscow | Wild | Syringe - 3 | Colts, castrated. |
| | | | 45-48 | 5/17/79 | Prineville | Wild | Dart - 4 | Open range. |
| | | | 49-51 | 6/28/79 | Pullman | Wild | Dart - 3 | |
| | | | 52 | 12/7/79 | Milton-Freewater | Wild | Dart - 1 | Adopted wild horse escaped. |
| | | | 53 | 4/7/80 | Parkland | Wild | Dart - 1 | Adopted wild horse escaped. |
| | | | 54-60 | 4/15/80-<br>7/18/80 | Pullman | Wild | Dart - 7 | 2 in combination with gallamine. |
| | 44 | SV | 1-44 | 8/29/78-<br>8/30/78 | Kooskia | Domes. Utility | Syringe - I.M. | 36 horses, 8 mules, blood samples, hot branded, 1 horse dead. |
| | 3 | SA | 000-148 | 10/6/79 | Salmon | Wild | Dart - 2<br>Pole - 1<br>Syringe | Blood sampled, 148 horses in fly chute, only 3 immobilized with Succ. Cl. |
| | 4 | SC | 1-3,7 | 10/3/79 | Challis | Wild | Dart - 4 | 1 from helicopter, 3 at trap. |

| Experimental Drug | Total Exper. | Code | Numbers | Dates | Location | Horse Type | Method | Comments |
|---|---|---|---|---|---|---|---|---|
|  | 29 | SBJ | 1-29 | 11/27/79-<br>11/29/79 | Burns Jct.<br>Owyhee | Wild | Dart - 29 mares | All helicopter work, blood samples, radio-collars (4 dead). |
|  | 24 | SK | 1-24 | 12/16/79-<br>12/19/79 | Challis | Wild | Dart - 24 | All helicopter work, anti-fertility drugs (10 dead). Blood samples on 4. |
|  | 97 | SG | 1-97 | 7/18/79-<br>9/20/79 | Pullman | Wild | Dart - 97 | 7 different horses. |
|  | 10 | SGB | 1-5 | 7/17/79 | Pullman | Domes. | Syringe - 5 | Exercise group. |
|  |  | $SGB_2$ | 100-104 | 2/19/79 | Pullman | Domes. | Syringe - 5 | Succ. Cl. controls |
|  | 108 | SB | 1-7 | 11/8/79 | Burns | Wild | Dart - 7 | All helicopter work. |
|  |  |  | 8 | 11/9/79 | Burns | Wild | Dart - 1 | Corral. |
|  |  |  | 9-46 | 11/9/79-<br>11/10/79 | Burns | Wild | Syringe - 38 | Bucking chute, freeze branded and blood samples. |
|  |  |  | 47-50 | 11/12/79 | Burns | Wild | Dart - 4 | All helicopter work. |
|  |  |  | 51-70 | 11/13/79 | Burns | Wild | Syringe - 20 colts | Bucking chute, freeze branded. |
|  |  |  | 71-94 | 11/14/79-<br>11/15/79 | Burns | Wild | Dart - 24 | All helicopter work (2 dead). |
|  |  |  | 101-114 | 7/22/80-<br>7/23/80 | Burns | Wild | Dart - 14 | All helicopter work, blood samples. |
| Total experiments | 446 |  |  |  |  |  |  |  |
| Total experiments in domestic horses | 121 | (61 different horses; 98 syringe and 23 dart injections) |  |  |  |  |  |  |
| Total experiments in wild horses | 325 | (185 different horses; 72 syringe and 253 dart injections) |  |  |  |  |  |  |
| Total helicopter experiments | 103 | (16 horses expired) |  |  |  |  |  |  |

Table 20. Induction and Recovery Times After Intramuscular Injections of Immobilizing Drugs in Domestic and Wild Horses

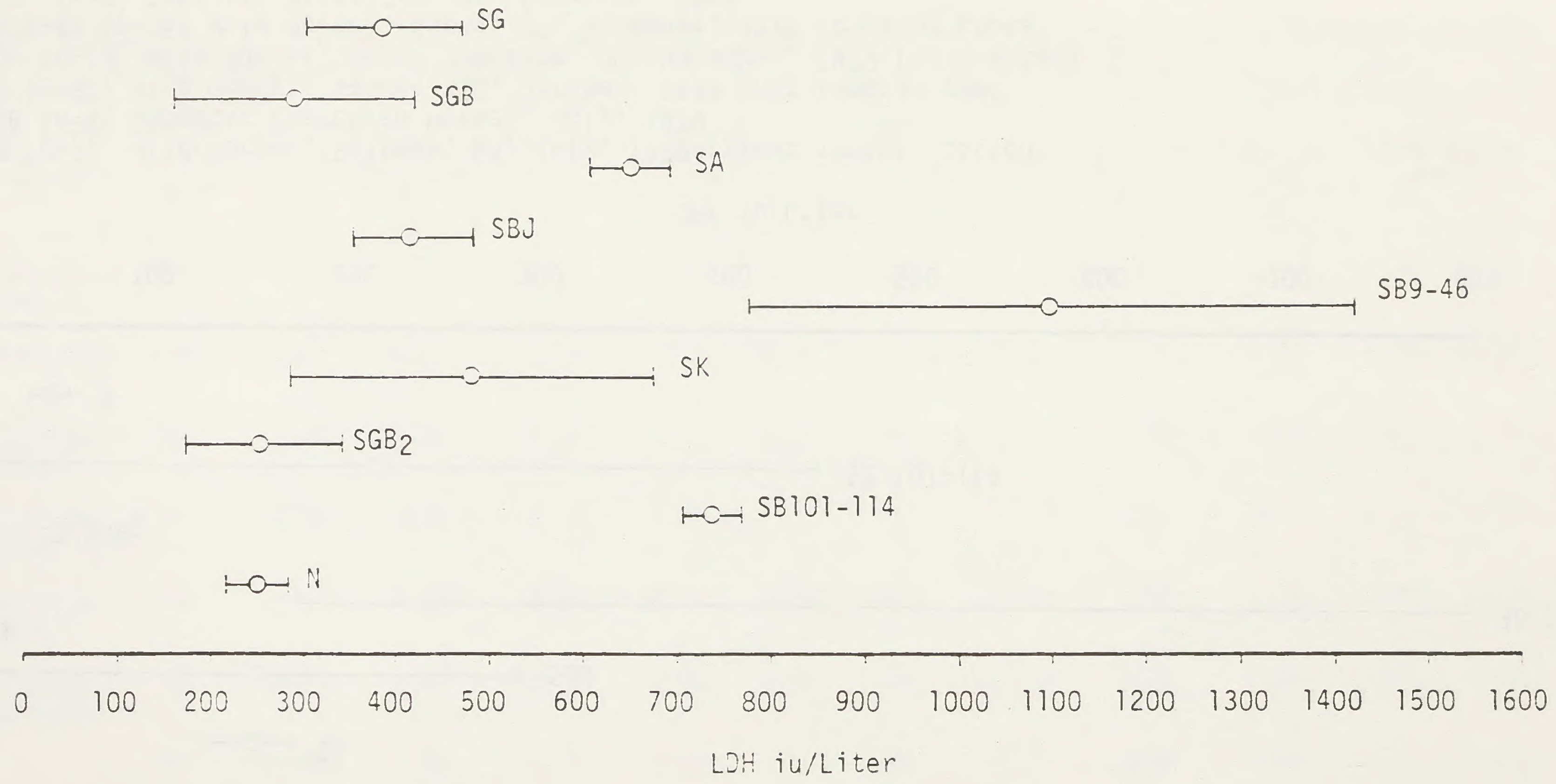
| | | Initial Induction Times (minutes) | | | | | Initial Recovery Times (minutes) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Exper. Group | Route of Injection | Number of Horses (n) | Mean ($\bar{y}$) | Standard Deviation (Sy) | Standard Error ($S\bar{y}$) | 95% Confidence Interval | Number of Horses (n) | Mean ($\bar{y}$) | Standard Deviation (Sy) | Standard Error ($S\bar{y}$) | 95% Confidence Interval |
| Succ Cl (S) | Syringe-Neck | 33 | 3.23 | 1.57 | 0.27 | 2.67 - 3.78 | 33 | 8.20 | 6.62 | 1.15 | 5.84 - 10.55 |
| Succ Cl (S) | Dart-Rump | 6.0 | 2.00 | 0.63 | 0.26 | 1.34 - 2.66 | 3.0 | 6.70 | 1.50 | 0.88 | 2.87 - 10.46 |
| Succ Cl (SB) | Syringe-Neck | 10 | 1.94 | 0.52 | 0.16 | 1.57 - 2.31 | 10 | 9.21 | 3.04 | 0.96 | 7.03 - 11.38 |
| Succ Cl (SB) | Syringe-Rump | 11 | 2.08 | 0.43 | 0.13 | 1.80 - 2.37 | 11 | 8.47 | 3.30 | 0.10 | 6.27 - 10.67 |
| Succ Cl (SV) | Syringe-Neck | 18 | 3.30 | 1.65 | 0.39 | 1.70 - 5.90 | 16 | 10.50 | 5.06 | 1.26 | 7.80 - 13.20 |
| Succ Cl (SV) | Syringe-Shoulder | 18 | 2.30 | 1.06 | 0.25 | 1.80 - 2.86 | 18 | 8.28 | 2.59 | 0.61 | 7.00 - 9.56 |
| Total Succ Cl | | 96 | 2.83 | 1.43 | 0.15 | 2.50 - 3.12 | 91 | 8.60 | 4.93 | 0.52 | 7.57 - 9.63 |
| Etorphine (E) | Syringe-Neck and Shoulder | 6 | 23.17 | 18.65 | 7.61 | 3.59 - 42.74 | Immobilization was antagonized at various times. | | | | |
| Gallamine (G) | Syringe-Neck and Shoulder | 17 | 19.62 | 14.13 | 3.43 | 12.35 - 26.88 | 17 | 28.06 | 49.63 | 12.04 | 2.54 - 53.58 |

Figure 1. Serum Creatine Phosphokinase (CPK) Activities in Domestic and Wild Horses After Immobilization with Succinylcholine Chloride. Values Shown are Means with 95% Confidence Limits.



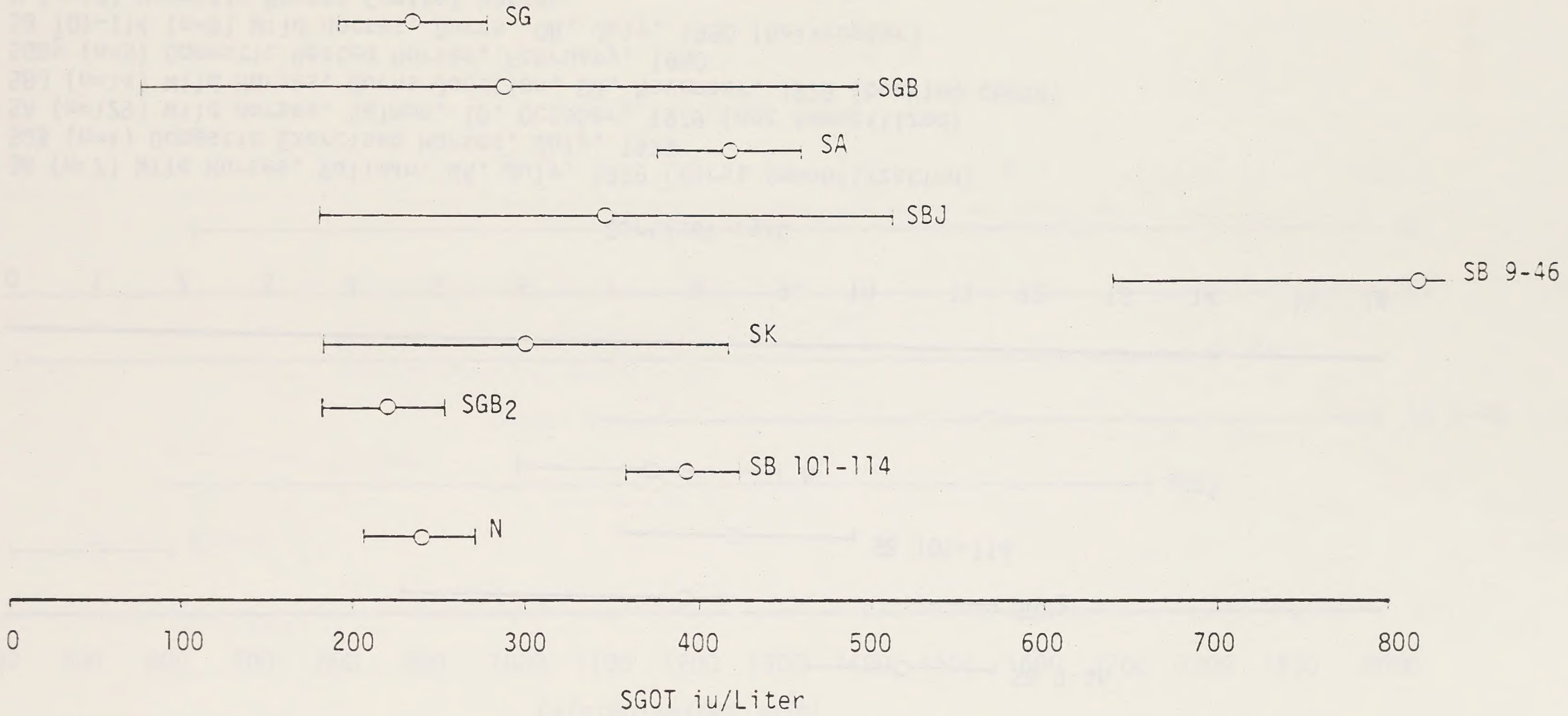
SG (n=7) Wild Horses, Pullman, WA, July, 1979 (first immobilization)
SGB (n=4) Domestic Exercised Horses, July, 1979
SA (n=61) Wild Horses, Salmon, ID, October, 1979 (not immobilized)
SBJ (n=14) Wild Horses, Burns Junction, OR, November, 1979 (helicopter)
SB 9-46 (n=36) Wild Horses, Burns, OR, November, 1979 (bucking chute)
$SGB_2$ (n=5) Domestic Rested Horses, February, 1980
SB 101-114 (n=9) Wild Horses, Burns, OR, July, 1980 (helicopter)
N (n=12) Domestic Rested Control Horses

Figure 2. Serum Lactate Dehydrogenase (LDH) Activities in Domestic and Wild Horses After Immobilization with Succinylcholine Chloride. Values Shown are Means with 95% Confidence Limits.



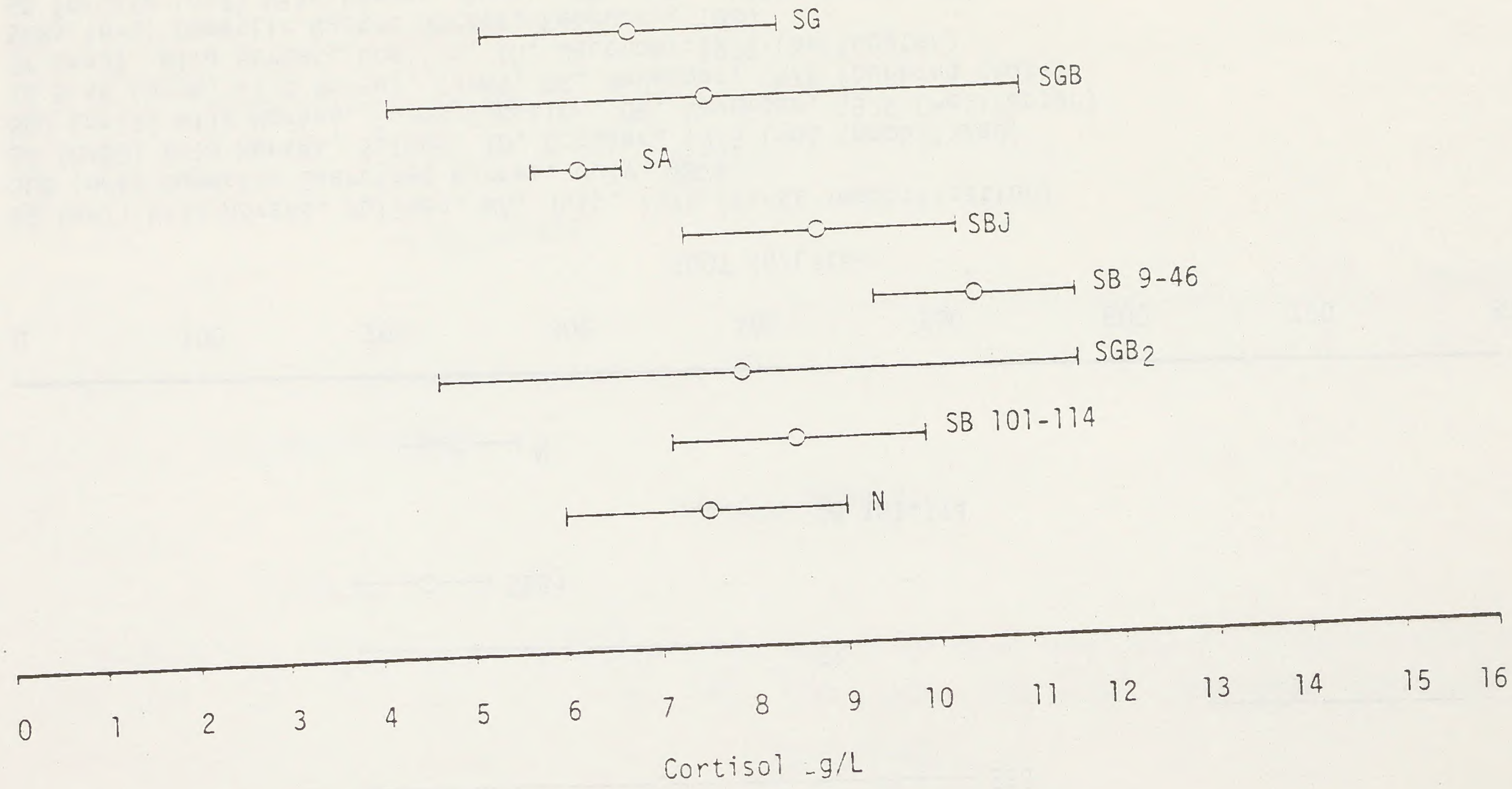
SG (n=7) Wild Horses, Pullman, WA, July, 1979 (first immobilization)
SGB (n=4) Domestic Exercised Horses, July, 1979
SA (N=60) Wild Horses, Salmon, ID, October, 1979 (not immobilized)
SBJ (n=28) Wild Horses, Burns Junction, OR, November, 1979 (helicopter)
SB9-46 (n=28) Wild Horses, Burns, OR, November, 1979 (bucking chute)
SK (n=3) Wild Horses, Challis, ID, December, 1979 (helicopter)
SGB$_2$ (n=5) Domestic Rested Horses, February, 1980
SB101-114 (n=9) Wild Horses, Burns, OR, July, 1980 (helicopter)
N (n=12) Domestic Rested Control Horses

Figure 3. Serum Glutamate Oxaloacetate Transaminase (SGOT) Activities in Domestic and Wild Horses After Immobilization with Succinylcholine Chloride. Values Shown are Means with 95% Confidence Limits.



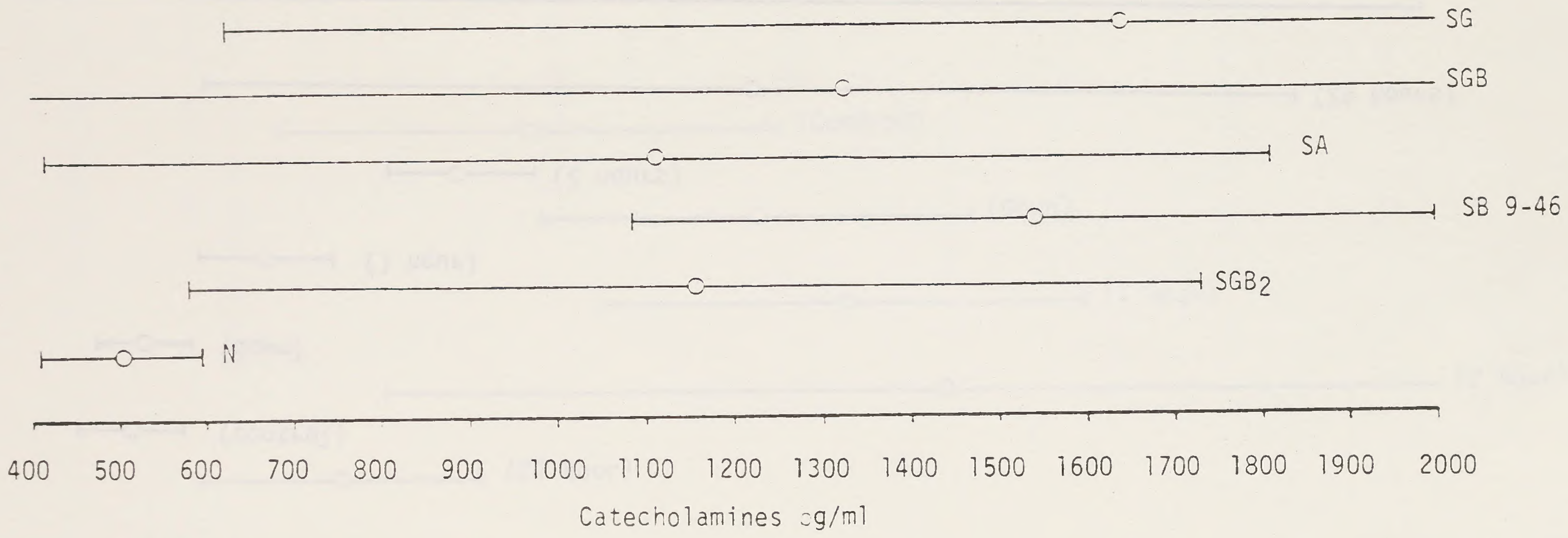
SG (n=7) Wild Horses, Pullman, WA, July, 1979 (first immobilization)
SGB (n=4) Domestic Exercised Horses, July, 1979
SA (n=60) Wild Horses, Salmon, ID, October, 1979 (not immobilized)
SBJ (n=14) Wild Horses, Burns Junction, OR, November, 1979 (helicopter)
SB 9-46 (n=36) Wild Horses, Burns, OR, November, 1979 (bucking chute)
SK (n=3) Wild Horses, Challis, ID, December, 1979 (helicopter)
$SGB_2$ (n=5) Domestic Rested Horses, February, 1980
SB 101-114 (n=9) Wild Horses, Burns, OR, July, 1980 (helicopter)
N (n=12) Domestic Rested Control Horses

Figure 4. Serum Cortisol Concentrations in Domestic and Wild Horses After Immobilization iwht Succinylcholine Chloride. Values Shown are Means with 95% Confidence Limits.



SG (n=7) Wild Horses, Pullman, WA, July, 1979 (first immobilization)
SGB (n=4) Domestic Exercised Horses, July, 1979
SA (n=129) Wild Horses, Salmon, ID, October, 1979 (not immobilized)
SBJ (n=14) Wild Horses, Burns Junction, OR, November, 1979 (bucking chute)
$SGB_2$ (n=5) Domestic Rested Horses, February, 1980
SB 101-114 (n=9) Wild Horses, Burns, OR, July, 1980 (helicopter)
N (n=12) Domestic Rested Control Horses

Figure 5. Plasma Catecholamine Concentrations in Domestic and Wild Horses After Immobilization with Succinylcholine Chloride. Values Shown are Means with 95% Confidence Limits.



SG (n=7) Wild Horses, Pullman, WA, July, 1979 (first immobilization)
SGB (n=4) Domestic Exercised Horses, July, 1979
SA (n=19) Wild Horses, Salmon, ID, October, 1979 (not immobilized)
SB 9-46 (n=28) Wild Horses, Burns, OR, November, 1979 (bucking chute)
SGB$_2$ (n=5) Domestic Rested Horses, February, 1980
N (n=12) Domestic Rested Control Horses

Figure 6. Serum Creatine Phosphokinase (CPK) Activities in Six Domestic Horses Before, During and After Immoblization with Etorphine (M-99). Values Shown are Means and 95% Confidence Limits.

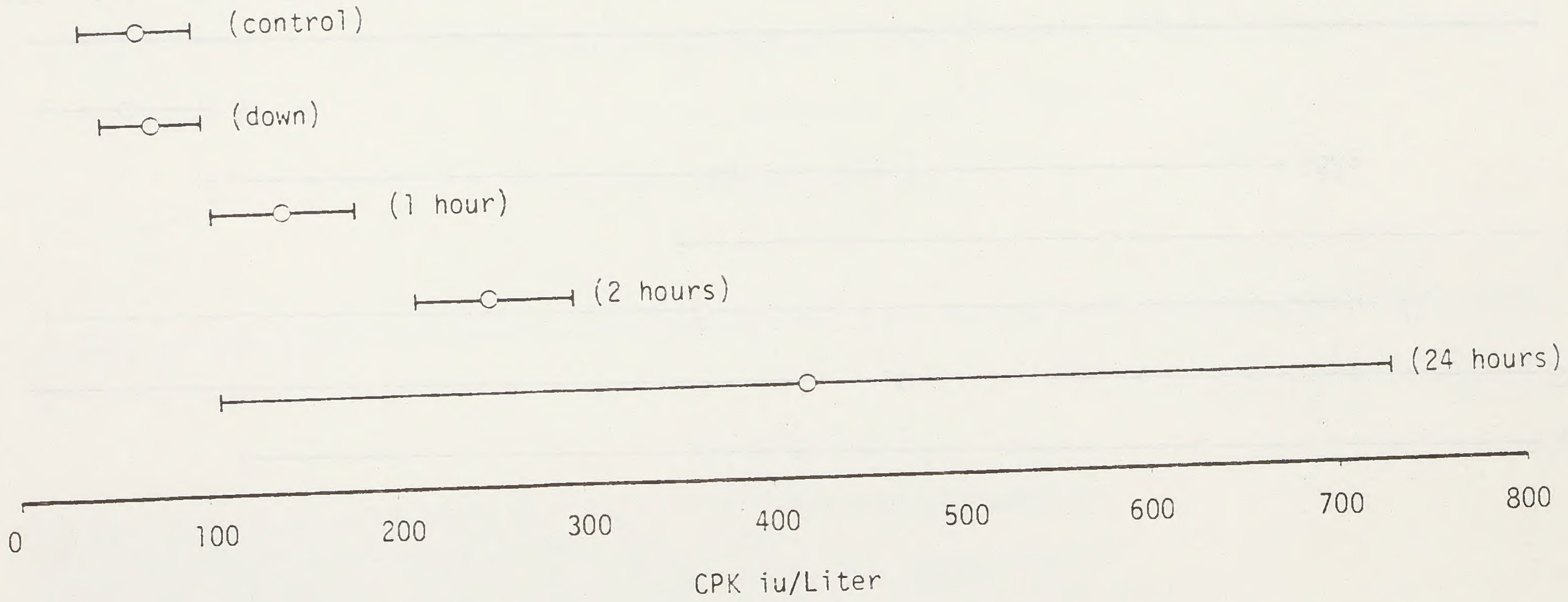
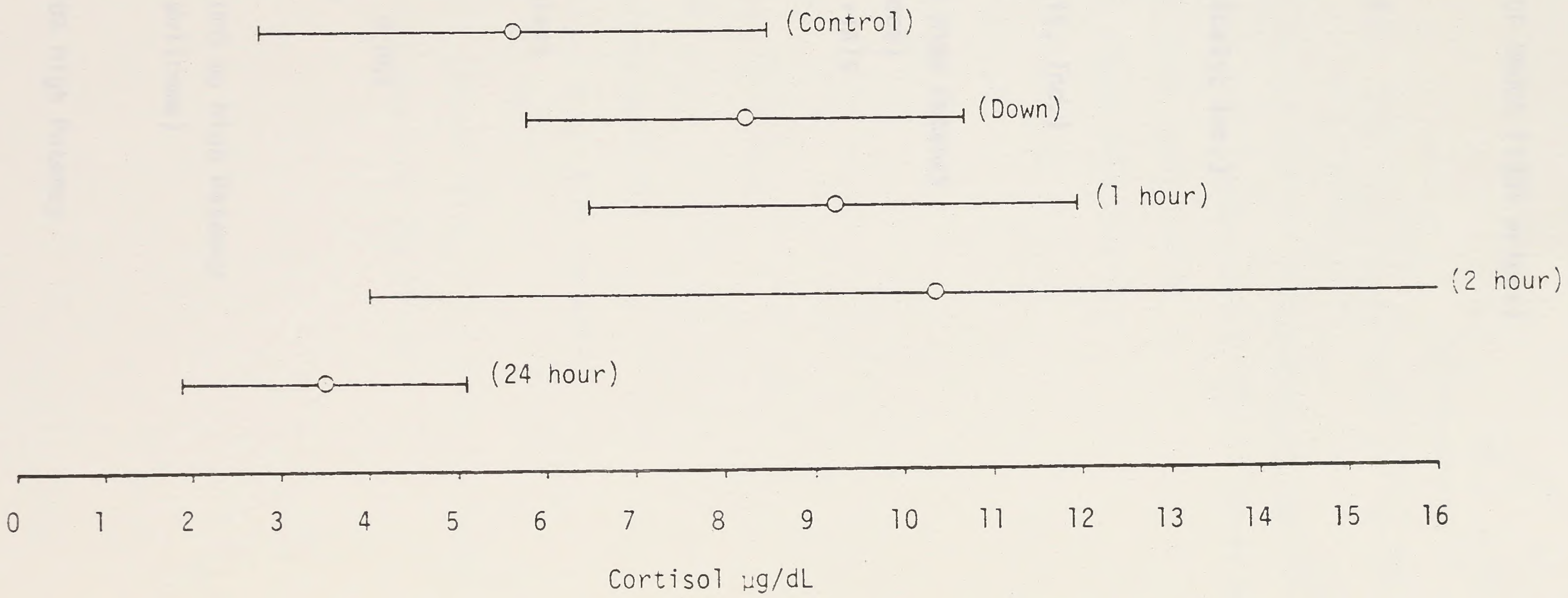


Figure 7. Serum Cortisol Concentrations in Six Domestic Horses Before, During, and After Immobilization with Etorphine (M-99). Values Shown are Means and 95% Confidence Limits.



## LIST OF DRUGS (1981 prices)

Acetylpromazine, 1%
(Acepromazine (R), Ayerst)
$6.59 per 50 cc vial

Diprenorphine, 0.1%
(M-50-50, D-M Pharmaceuticals, Inc.)
$56.20 per 20 cc vial

Etorphine, 0.1%
(M-99, D-M Pharmaceuticals, Inc.)
$56.20 per 20 cc vial

Gallamine Triethiodide, 10% High Potency
(Flaxedil (R), Davis & Geck)
$30.07 per box of 12 vials

Guaifenesin (GG) $25.00/Kg

Ketamine, 10%
(Ketaset (R), Bristol)
$6.50 per 10 cc vial

Morphine Sulfate, 15 mg tablets
(Eli Lilly & Co.)
$5.60 per bottle

Neostigmine Methyl Sulfate, 0.05%
(Prostigmine (R), Roche)
$2.10 per 10 cc vial

Succinylcholine Chloride, 1000 mg High Potency
(Anectine (R), Burroughs Wellcome)
$1.48 per 1000 mg

Succinylcholine Chloride, 10% High Potency
(Sucostrin (R), Squibb)
$3.60 per 10 cc vial

Thiamylal Sodium, 5 Gm
(Surital (R), Parke-Davis)
$4.75 per 5 Gm vial

Xylazine, 10%
(Rompun (R), Haver-Lockhart)
$37.55 per 50 cc vial

# LIST OF EQUIPMENT

Oxygen Delivery System

- a. Hudson portable unit No. 5006, with Demand Valve and Two Stage Regulator (Hudson Co.) approximately $400.00
- b. "E" size medical oxygen cylinder for Hudson portable unit ($95.00).
- c. Mark 7 Respirator (Bird Corp.) approximately $1,200.00.

Resuscitation bellows (Avon, Raft Pump), $40.00

Palmer "Cap-Chur" Equipment (Nasco 1980 Catalog)

- Cartridge Rifle, 50 calibre $225.00
- $CO_2$ Rifle, 50 calibre, $180.00
- Complete "Cap-Chur" Dart $12.00

Paxarms Capture Equipment

- Cartridge Rifle, $800.00
- Syringe Projectile $5.00-$10.00 each

Pneu-Dart Capture Equipment

- Cartridge Rifle, 50 calibre, $205.00
- Liquid Dart (0.7cc) without drug, $.75 per dart
- Prod Syringe, 6' Model, $52.00

Nel-Spot Paint Pellet Pistol (Nelson Paint Co.) c̄ pellets & holder approx. $100.00

Qwik-Point gun sight (Weaver) approximately $50.00

# ADDENDUM

## ACKNOWLEDGEMENTS

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The most generous and enthusiastic support was provided by my wife, Alma, and by my sons and daughters.

# PHYSIOLOGIC RESPONSES OF FERAL HORSES TO SUCCINYLCHOLINE IMMOBILIZATION

## ABSTRACT

By LeRoy V. Gallagher, D.V.M., M.S.
Washington State University, 1980

Chairman: Ronald E. Borchard

The need to formulate humane capture and restraint methods for feral horses was the purpose of the study. Two questions were addressed: (1) What are the normal values for physiologic parameters relevant to an evaluation of stress and exercise? (2) How are these parameters altered in management practices requiring horse restraint?

Serum enzyme activities of creatine phosphokinase (CPK), lactate dehydrogenase (LDH), and glutamate-oxaloacetate transaminase (SGOT) were evaluated in captive, feral horses and in rested, exercised, and utility-type domestic horses after succinylcholine chloride (SCh) immobilization. Serum cortisol and plasma catecholamine concentrations in feral horses were examined. A data base, suggesting no significant differences in these parameters between domestic and feral horses, was generated.

Physiologic responses to repeated projectile intramuscular administration of SCh for restraint of captive, feral horses were monitored to assess the safety and humaneness of the method. The safe and practical use of SCh in management of unapproachable horses suggests the method as a valuable procedure for studing alternate restraint techniques in feral equidae.

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# INTRODUCTION

The problems of managing feral horses (Equus caballus) have resulted in an increased awareness of our lack of knowledge regarding the normal physiologic status of this unique population. Although research has been conducted in exotic equidae, relatively little is known regarding the normal physiologic values for feral equidae of North America.[1-3] An extensive tabulation of physiologic values was reported for 4 feral American burro foals (E. asinus) in 1978.[4] Investigations of circulating reproductive and adrenocortical steroid hormone levels have been conducted from 1973-79 in the Pryor Mountain National Wild Horse Range, Montana, in captive feral horses.[5-7] Only in recent years has attention been directed to the population and social dynamics of feral equidae in this country and, at a recent symposium, thirty papers were presented on the subjects of ecology, behavior, and reproduction.[a]

Questions generated within management agencies, as well as within concerned legislative, research, and protectionist groups, indicate a need for investigation of physiologic values that characterize the feral horse in order to formulate efficient management methods involving restraint. The need for humane methods of restraint for feral horses was the stimulus for the initiation of this study.[8] Two questions pertaining to feral horses on public ranges were addressed: (1) What are the normal values for physiologic parameters relevant to an evaluation of stress and exercise? (2) How are these parameters altered in management practices requiring horse restraint?

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[a] The ecology and behavior of feral horses. Wild Horse Symposium Proceedings, University of Wyoming, Laramie. Sept. 6-8, 1979. (In print).

The role of equine serum enzymes as an index of fitness and their relationships to varying degrees of exercise and fatigue has been investigated.[9-12] The association of observed changes in serum enzyme activities with myocardial infarction in man and skeletal myopathies in man and animals gave impetus to these studies. Differential diagnoses were made possible by an examination of relative serum enzyme activities, and prognostic or predictive statements could be made depending upon the actual levels of serum enzyme activities and their relative disappearance rates.[11,12] The relationship of serum glutamate-oxaloacetate transaminase (SGOT) activity to changes in performance of horses during training has been noted.[10] Comparative studies of creatine phosphokinase (CPK) and SGOT activities in horses exhibiting paralytic myoglobinuria and of CPK, SGOT, lactate dehydrogenase (LDH), and aldolase in hunters and Thoroughbred horses during training established these procedures as valuable diagnostic and prognostic aids.[11,12] Similar studies have been reported in sheep and swine.[13,14] Aside from recent work in African zebra,[3] few studies have involved serum enzyme dynamics in feral equidae.

Creatine phosphokinase is responsible for a number of transphosphorylation reactions involving adenosine triphosphate (ATP) which is important in normal energy transfer from one system to the other. In skeletal muscle, CPK is found in the mitochondria and involves the phosphorylation of creatine. In the sarcoplasmic reticulum, CPK is responsible for regeneration of ATP from adenosine diphosphate (ADP) and creatine phosphate, which provides energy to the ATP-dependent sodium pump, essential to skeletal muscle relaxation. Creatine phosphokinase is a dimeric enzyme occurring in three isoenzyme forms, of which the MM form ($CPK_3$) predominates in skeletal muscles.[15] This form is also the isoenzyme found in blood, and changes in CPK activities in serum are related to physiologic and pathologic events occurring in skeletal muscles as a result of exercise, fatigue, trauma, or myopathy. It has been suggested that the release of CPK from active muscle is the result of hypoxia, hypercapnia, and acidosis which cause an increase of muscle cell membrane permeability.[15] Elevated CPK activity in equine serum has been associated with exercise and depends upon type, severity, and duration of exertion, as well as the animal's degree of training.[12]

An early report showed normal CPK activities in serum of mares and geldings had a mean and standard deviation (SD) of 1.3 ± SD 0.9 International Units per Liter (iu/l), but suggested slightly higher normal values might be expected in stallions.[11] Later reports showed normal CPK activities to be considerably higher. Fifteen endurance horses, tested while at rest, showed normal levels with mean and standard error of the mean (SE) of 19.0 ± SE 2.4 iu/l.[16] In a group of 10 normal mares and geldings, on controlled exercise, mean values were 115.0 ± SD 39.0 iu/l.[12] Studies in ponies showed 9.6 ± SE 0.8 iu/l[17] and, in a four-year study of 25 captive Grant's zebra, mean reference values for CPK were 81.0 ± SE 12.0 iu/l.[2]

Lactate dehydrogenase is a tetrameric enzyme in the cytosol of myocardial and skeletal muscle cells and in hepatocytes. Five isoenzymes of LDH have been identified, each having a specific affinity for the substrate, pyruvate. The principal isoenzyme of skeletal muscle, $\mathrm{LDH}_5$, is responsible for reduction of pyruvate to lactate in muscle undergoing intense activity. Reduction of pyruvate is concomitant with oxidation of reduced nicotinamide adenine dinucleotide (NADH) to $\mathrm{NAD}^+$, the coenzyme required in the glycolytic pathway at the glyceraldehyde-3-phosphate level under anaerobic conditions. During strenuous skeletal muscular activity, LDH provides a sparing effect in muscle metabolism that bypasses the citric acid cycle in the mitochondria and provides a supply of $\mathrm{NAD}^+$ for continued glycolysis. The appearance of LDH of muscle origin in blood is thought to result from escape of the enzyme from the sarcolemmal sheath as a result of increased permeability caused by excessive activity of muscle tissue cells. In the absence of hepatic or myocardial disease, the LDH isoenzyme present in the serum is predominantly of skeletal muscle origin.[18] Serum LDH has been shown to be an index of skeletal muscle functional change, and elevated levels correlate well with varying degrees of exercise, work, training, and skeletal muscle fatigue. Increases of 25 percent in LDH activity have been associated with long-term training in Thoroughbred horses. In 10 normal horses under controlled exercise, it was reported that reference values ranged from 357.0 to 944.0 iu/l with mean values of 645.0 ± SD 168.0 iu/l.[12]

Glutamate-oxaloacetate transaminase, a cytoplasmic enzyme, catalyzes the reversible transamination of aspartic acid to $\alpha$-ketoglutarate in a reaction closely associated with the citric acid cycle in muscle and hepatic metabolism. Although present in myocardial and hepatic tissue, SGOT has been considered an index of skeletal muscle functional change when clinical evidence of myocardial or hepatocellular disease was not present.[10] Early reports of GOT values in normal horse plasma showed a range of 72.0 to 89.0 iu/l.[9-11] Reference values of approximately 67.0 iu/l were reported for GOT in the plasma of burros.[4] Mean reference values of SGOT for captive zebra varied from 100.0 to 170.0 iu/l in two studies.[2,3] Recent studies indicate SGOT activities for normal horses to be considerably higher, 285.0 ± SD 42.0 iu/l.[12]

In light of the wide range in values reported in the literature for the 3 serum enzymes considered, it seemed appropriate to establish normal values for domestic horses in this geographic area for the purposes of this study.

The role of the adrenal gland in homeostasis has been the subject of extensive study in both man and animals, and the distinctive functions of its cortical and medullary components in response to environmental change has long been recognized.

Changes in plasma glucocorticoid levels have been related to degrees of stress and exercise in the horse and to stress in cattle, sheep, and white-tailed deer.[7,19-22] Equine adrenocortical function is controlled by mechanisms similar to those of other mammalian species.[19] Stressors influence the activation of the hypothalamic-hypophyseal-adrenal axis causing release of adrenocorticotropic hormone (ACTH) which acts upon the adrenal cortex to cause secretion and biogenesis of glucocorticoid hormones. Cortisol has been identified as the major glucocorticoid hormone in equine blood; a ratio of 168:1, cortisol to corticosterone, has been reported for 3 stallions.[7,19,23] Though corticosterone and cortisone are present, cortisol provides a satisfactory index of hypothalamic-adrenal functional response.[24]

A daily rhythm of adrenocortical function resulting from a circadian variation of ACTH secretion in equidae has been reported by several investigators and has been described in the feral horse.[19,23,25,26] Diurnal variation in glucocorticoid levels characterizes this parameter in horses, suggesting that careful scrutiny should be applied in comparisons of data from several sources. It is generally agreed that peak levels occur in the morning between hours 6 and 10.

Assay procedures for circulating cortisol usually specify plasma samples. However, comparable results are obtained using serum by the radioimmunoassay (RIA) method.[27] Using the competitive protein-binding method, one group found mean total plasma corticosteroid levels of 5.12 ± SD 1.67 micrograms per deciliter (μg/dl) in 92 horses.[25] Subsequently, in a different study, lower mean concentrations (1.37 ± SD 0.40 μg/dl) were recorded for 4 mares using this radioassay.[23] In the former group of horses, no significant differences in plasma cortisol levels were related to age, sex, or pregnancy.[25] Mean total corticosteroid concentrations of 40.2 ± 6.3 (SD) nanograms/milliliter (ng/ml) of plasma were reported in 3 wild stallions.[7] In an evaluation of handling methods for feral horses, it was concluded that measurement of circulating corticosteroids was a useful and accurate means of objectively gauging stress.[7]

In most mammalian species the sympathetic neurohumoral transmitter substances produced within the sympathoadrenomedullary axis are the catecholamines, norepinephrine, and epinephrine. Adrenal medullary chromaffin cells are the primary site for the conversion of norepinephrine to epinephrine, the principal hormone secreted by this gland. These cells serve a unique functional role in the autonomic nervous system in that they behave as postganglionic neurons, in the production and storage of catecholamines, and as endocrine organs, in the release of these substances into the circulation in response to sympathoadrenal stimulation. Receptors in organs far removed from the adrenal gland respond to circulating catecholamines to an extent proportionate to their relative concentrations, and in the case of fright, total mobilization of the sympathetic segment of the autonomic system occurs, homeostatic mechanisms are temporarily suspended, and the animal either flees or turns to confront the danger. The catecholamines, especially epinephrine, recruit those systems subserving rapid mobility.

Though studies have been conducted to ascertain the biochemical and physiological effects of the catecholamine administration in horses, little information was available regarding the normal values for circulating catecholamines in horses.[28,29] The physiologic manifestations of fear, excitement, and exertion in horses, as reflected by changes in plasma catecholamine levels, have not been examined extensively. With the appearance of a radioenzymatic assay system for plasma catecholamines, it was decided to examine this parameter in the present study.

Among the available drugs suitable for use in capture and restraint of unapproachable horses, those classified as neuromuscular blocking agents were selected for trial. As an outgrowth of preliminary work with this class, succinylcholine (SCh), administered intramuscularly, was judged to be an effective immobilizing agent. The mechanism of action of SCh is an interference with normal acetylcholine-mediated transfer of impulse at the myoneural junction characterized as a non-competitive depolarization of the postjunctional membrane. The delay in repolarization of the postsynaptic membrane results in a flaccid paralysis of the muscle fiber and, though transient, provides adequate restraint for short periods. Enzymatic biotransformation of the molecule, through the agency of plasma cholinesterase, terminates the effect of the drug.

Recent reviews of the clinical pharmacology and kinetics of biotransformation of SCh have appeared.[30, 31] The clinical usefulness of SCh lies in its ability to cause muscle relaxation in anesthetized surgical patients. Human and veterinary anesthesiologists employ SCh effectively to reduce the need for deep anesthesia, especially for prolonged procedures. With the introduction of SCh to the veterinary profession about 1955, many veterinarians used the drug in standing horses as a restraint drug for minor surgical procedures. Since SCh has no anesthetic or analgesic properties, its use in unanesthetized equine surgical patients was strongly criticized. Reservations about its use as an immobilizing drug in equines are also expressed, based upon reports of adverse reactions that may result.[32] As with any potent drug, SCh has been recognized to possess pharmacologic properties that could lead to undesirable side effects. Among these are muscle pain, as a result of fasciculations in large muscle masses; cardiovascular effects characterized by tachycardia, hypertension, and dysrhythmias, associated with increased sympathetic discharge; and myocardial injury as a direct result of hypercapnia and hypoxia.[30]

Neuromuscular blockade results in a progressive paralysis, from the distal support muscles to the respiratory muscles of the thorax and the diaphragm, in a gradient that is dose related. Effective immobilizing doses depress the respiration to the degree that these muscles are affected. At higher doses, flaccid paralysis of respiratory musculature and total apnea may ensue, with resultant hypoxemia, hypercapnia, and acidosis. Asphyxia and death may result if mechanical ventilation of the animal is delayed.

Although other mechanisms have been proposed, the predominant cardiovascular effects of SCh are believed to be a manifestation of increased sympathetic discharge associated with fright. Reflex mechanisms, due to increased sympathetic tone and increased peripheral vascular resistance, also contribute to the transient hypertension and tachycardia seen with the use of this drug in the immobilization of standing horses. Myocardial vascular injury with extravasation of blood into and around the myocardium has been described.[32] The degree to which these local vascular accidents represent the effects of antemortem events, as distinguished from agonal injury to the myocardium and its vasculature at the time of death, has not been determined. Postmortem findings in horses that have been adequately ventilated throughout the apneic period, and have not suffered agonal struggle in death, have not been described.

The selection of SCh for use in this study followed an evaluation of it and other chemical restraint agents in a pilot study conducted in a group of domestic horses. Certain undesirable features of each of the other drugs resulted in postponement of further work with them. Among the criteria established for evaluation of a drug were considerations relative to drug availability, ease of administration, and small dose volume. Rapid absorption and effect were required, since extended latency periods were undesirable from a management standpoint. Safety of some of the agents, for both the horses and the personnel, was in question because of toxicity or prolonged effects that were observed. Those drugs that might lend themselves to abuse by personnel were withheld for future study.

Notwithstanding the known and suspected undesirable features of SCh, the drug was considered to satisfy a larger number of the important criteria. Judgement regarding the safety and effectiveness of SCh under field conditions could be established experimentally.

In this study, consideration was given to the fact that rapid immobilization of the animal with SCh could be effected with the consistency desired and the duration of effect was sufficient to complete most management procedures. Rapid recovery, with no apparent prolonged after-effects, was a desirable property of this drug. It remained to be determined to what extent its use would satisfy management requirements.

## MATERIALS AND METHODS

### Introduction

Domestic horses were used to establish normal values and values that relate to exercise and work in an effort to establish parallels to the physiologic status of free-roaming or recently captured feral horses. To avoid possible drug interactions, horses were selected that had had no recent medication. Plasma cholinesterase inhibiting drugs, such as organophosphate anthelmintics, were withheld for 30 days preceding the experiments. The horses at our facility had not been in training and had been maintained on adequate rations, including access to pasture grasses and good quality alfalfa hay. All were clinically normal and sound.

### Experiment 1

#### Group 1, Trial 1

Twelve adult domestic horses (5 geldings and 7 mares), of Thoroughbred, Quarterhorse, and saddle-type parentage, were used to establish normal values for serum CPK, LDH, and GOT activities and for serum cortisol and plasma catecholamine concentrations in rested horses not in training.

#### Group 1, Trial 2

Five horses of Group 1 were immobilized with SCh, and blood specimens were drawn while the animals were recumbent, at 1 hour (hr) following recovery (post-immobilization), and at 24, 48, and 72 hr post-immobilization. Serum CPK, LDH, GOT, cortisol, and plasma catecholamine determinations were made, to assess the effect of SCh immobilization in rested domestic horses.

Group 1, Trial 3

Four horses of Group 1 were transported by truck to an exercise facility. After an exercise regimen of a brisk walk and forced canter over a one-mile course lasting about 20 minutes, each horse was immobilized with SCh and blood was drawn while the horse was recumbent. A second blood specimen was obtained 72 hr post-immobilization. Serum CPK, LDH, GOT, cortisol, and plasma catecholamine determinations were made, to assess the effects of exercise and SCh immobilization in rested domestic horses.

Group 2

Nineteen medium, utility-type, adult geldings and mares from a commercial outfitter's pack-string were examined in a field trial. These horses were considered to be conditioned to work and were physically fit. All were clinically normal and sound and were maintained on adequate rations. Blood specimens were drawn while the utility horses were at rest. Each horse was immobilized with SCh. While recumbent, most of these horses were branded by the owner. A second blood specimen was drawn 1 hr post-immobilization. Serum CPK, LDH, GOT, cortisol, and plasma catecholamine determinations were made, to establish normal values for the group and to assess the effects of SCh immobilization and branding in rested, utility horses.

Group 3

Seven male feral horses (5 adult geldings and 2 juvenile colts) were used in the study. Testing of this group commenced after the horses had been in captivity approximately 3 months. Though they were confined to pasture, no attempt had been made to gentle or train the feral horses. The ration was good quality alfalfa hay. The horses were clinically normal and sound.

The feral horses were immobilized with SCh, and blood specimens were obtained while they were recumbent. Serum CPK, LDH, GOT, cortisol, and plasma catecholamine determinations were made, to establish reference values for these parameters in captive feral horses after SCh immobilization. Values in feral horses after initial SCh immobilization would be compared to those of domestic horses at rest, after exercise, and during periods of restraint.

## Experiment 2

Physiologic responses of captive feral horses to repeated use of SCh for restraint were considered to be valid criteria upon which to base judgments regarding the safety and humaneness of the method. An appreciation of possible adverse sequellae was needed to assist in the conclusional process.

Five feral horses of Group 3 (3 to 5 years of age) were immobilized with SCh the same approximate hour at 72 hr intervals for 30 days (July 18 through August 17) for eleven actual experiences with the drug. Blood was drawn in each trial.

Serum CPK, LDH, GOT, cortisol, and plasma catecholamine determinations were recorded to establish trends in those parameters over time.

## Experiment 3

The effects of repeated use of SCh immobilization at short intervals in captive feral horses were examined with the purpose of ascertaining the probable limits to which the method could be used under field conditions.

Two feral horses of Group 3, one adult gelding (2) and 1 juvenile colt (6), were immobilized with SCh at hr 0, 1, 3, and 5 on day 1, and blood was drawn in each trial while the horse was recumbent. The response in each horse was monitored at 72 hr intervals over 30 days, as outlined in Experiment 2, above. Similarily, on day 30, one adult gelding (1) and 1 juvenile colt (7), whose responses had been recorded in Experiment 1, were immobilized with SCh at hr 0, 1, 3, and 5 on day 30, with a view to comparison of possible physical tolerances with those of horses 2 and 6. It was thought that selecting 2 adult and 2 juvenile horses for the experiment might demonstrate an age-related difference in response. Serum CPK, LDH, GOT, cortisol, and plasma catecholamine determinations were recorded for each of the 4 horses over the 14 trials.

In all cases the drug, succinylcholine chloride injection U.S.P. 100 mg/ml,[b] was administered by deep intramuscular injection. A dosage range of 0.45 to 0.55 milligrams per kilogram of body weight (mg/kg) was used, and the total dose was based upon estimates of body weight. In instances involving unapproachable horses, the drug was delivered using a capture gun and dart system.[c] A 3 cc capacity syringe-dart was propelled by one of three available cartridge charges designed for various ranges. A prod syringe[d] was used when the feral horses could be approached in a stock or chute. Domestic horses received the drug by routine intramuscular administration.

All tests were conducted between hours 7 and 11. An evaluation of the horse's physical status was made prior to the time each dose was administered. Estimated weights and total dose were recorded, as well as site of injection, latency period, and the character of the drop. Pulse, respiration, rectal temperature, degree of paralysis, and mucous membrane coloration were recorded, and note was made of capillary-refill time. Total time of immobilization was recorded.

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[b] Sucostrin, E.R. Squibb and Sons, Inc., Princeton, NJ 08540

[c] Palmer Chemical and Equipment Co., Inc., P.O. Box 867, Palmer Village, Douglasville, GA 30134

[d] Pneu-Dart, Inc., P.O. Box 1415, Williamsport, PA 17701

When it became necessary to resuscitate an immobilized horse, a raft pump or bellows,[e] available at most outdoor stores, was used with the hose-end adapted for insertion into the horse's ventral nasal meatus by use of an 8-inch length of 25 mm endotracheal tube of soft red rubber.[f] The pump delivers approximately 2 liters of air with each stroke, and two or three strokes are sufficient to inflate the lungs of an average-sized horse experiencing drug-induced apnea. By alternately grasping and releasing the nostrils of the horse, insufflation and passive expiration could be controlled in a cadence resembling voluntary respiration. When a horse was immobilized, first consideration was given to an assessment of imminent apnea, as signaled by what came to be called "asphyxiation struggle." In those instances when this phenomenon occurred, resuscitation methods were applied immediately, and the animal was ventilated throughout the apneic period and until voluntary respiratory efforts demonstrated adequate tidal volume. When certainty of adequate oxygen exchange was established, recordings were made, and blood specimens drawn.

Blood collection was by jugular venapuncture, using evacuated blood collection tubes.[g] Three specimens were collected from each horse: one 15 ml (M3218) tube for serum harvest, one 2 ml (M3272QS) tube, containing heparin, for hematologic determinations, and one 5 ml (M3206) tube, containing a solution of ethylene glycol-tetraacetic acid (90 mg/ml) as the anticoagulant and glutathione (60 mg/ml) as the antioxidant, for plasma catecholamine assay. Using a 20 gauge multi-sample needle and guide,[g] all specimens could be drawn through the same needle.

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[e] AVON, Seagull Mrine, 1857 McGaw Ave., Ervine, CA 92714

[f] North American Dräger, P.O. Box 121, Telford, PA 18969

[g] Becton-Dickinson and Co., Rutherford,NJ 07070

The blood for serum collection was allowed to form a firm clot at ambient temperature in a covered styrofoam box before refrigeration. On return to the laboratory, the serum was harvested after centrifugation at 2200 rpm for 10 minutes and divided into appropriate aliquots for disposition. One portion of serum was sent to a commercial laboratory[h] for selected serum chemistry, metabolite and enzyme assays. One portion was delivered to the Washington State University Clinical Diagnostic Laboratory for two serum enzyme assays, and one portion was retained in our laboratory for serum cortisol assay. The plasma for catecholamine determinations was harvested after centrifugation at 2200 rpm for 10 minutes and was retained in our laboratory. Both the serum cortisol and plasma catecholamine specimens were refrigerated at -68°C until the assays could be run.

## Analytical Procedure

Creatine phosphokinase determinations were based upon the methods of Oliver and Rosalki which involve the production of ATP and its eventual function in reduction of $NAD^+$ to NADH.[33,34] Creatine phosphokinase activity is directly proportional to NADH production and can be quantified spectrophotometrically. Since negligible loss of CPK activity occurs when serum is frozen, specimens were allowed to accumulate over several weeks before being processed.[15]

Serum glutamate-oxaloacetate transaminase and LDH activities were determined by an automated analyzer system based upon the method of Kessler et al. involving the $NAD^+$ oxidation-reduction reaction and utilizing the absorptive properties of NADH at 340 nm.[35] Where this spectrophotometric method for SGOT employs a two-step reaction resulting in the oxidation of NADH, the LDH reaction is a direct reduction of the coenzyme.

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[h] Treasure Valley Laboratories, Boise, ID

The RIA method, based upon the competitive binding principles of Yalow and Berson,[36] available in kit form,[i] was used for serum cortisol determinations.

The total catecholamine radioenzymatic assay method described by Passon and Peuler was used for catecholamine determinations. This assay utilizes the enzymatic O-methylation of epinephrine and norepinephrine with a tritiated methyl component and was found to be sufficiently sensitive for the purposes of this study.[37] This assay is also available in a kit.[j]

Where applicable, Student's t statistic was used to compare means.[38] For unpaired observations with equal variances, Student's pooled-t statistic was used; for paired observations, Student's paired-t statistic was used.[k] Paired or unpaired observations with unequal variances were analyzed using the Cochran and Cox t-prime approximation. Linear correlation analyses were applied to bivariate observations.[l] A probability of less than 0.05 was considered significant ($P < 0.05$).

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[i] GammaCoat $[^{125}]$ Cortisol, Radioimmunoassay Kit, Clinical Assays, Division of the Travenol Laboratories, Inc., Cambridge, MA 02139

[j] Cat-a-Kit$^{tm}$ (catecholamines radioenzymatic assay kit $[^{3}H]$, Upjohn Diagnostics, Kalamazoo, MI 49001

[k] Wang 500, Wang Laboratories, Inc., 836 North Street, Tewksbury, MA 01376

[l] Tl-55, Texas Instruments Incorporated, Dallas, TX

# RESULTS

## Experiment 1: Normal Values for Physiologic Parameters Relevant to Evaluation of Stress and Exercise

### Serum Enzymes

Normal mean values for CPK, LDH, and SGOT activities in serum of 12 rested, untrained, domestic horses (Group 1, trial 1) are shown in Table 1. The values for CPK and LDH differ considerably from those reported earlier.[11,12,16] Mean SGOT values compare well with recently reported findings for normal horses.[12]

Values for CPK, LDH, and SGOT activities in serum of 5 horses (Group 1, trial 2) in response to SCh immobilizaiton are shown in Table 2. No change in CPK activity was observed at the time of immobilization, and a moderate elevation was observed at 1 hr. At 24 hr, mean CPK values were significantly increased over normal values for the 5 horses (paired-t, one-tailed test, $P < 0.05$). At 48 hr, wide variation in response was noted because of a high value (374 iu/l CPK) in 1 horse (SG 102), which value was considered an artifact. The mean for the other 4 horses at 48 hr was 52.75 iu/l, indicating a lowering of CPK activity at or before 48 hr. At 72 hr, CPK activity had attained normal levels.

No appreciable change was observed in LDH activity at 1 hr post-immobilization. The mean values shown at 48 and 72 hr were significantly increased over normal values (paired-t, one-tailed test, $P < 0.05$).

No change in SGOT activity was observed at 1 hr post-immobilization. At 24 hr, a moderate increase was apparent but was not significant ($P < 0.05$).

At 48 and 72 hr post-immobilization, mean values for SGOT were significantly increased over normal values for the 5 horses (paired-t, one-tailed test, $P < 0.05$).

Though there was a significant increase in CPK, LDH, and SGOT activities at some point between 1 and 72 hr following SCh immobilization in rested, untrained, domestic horses, the mean values shown at 72 hr in these parameters were not significantly different from normal values for Group 1 (pooled-t, two-tailed test, $P < 0.05$). Only moderate changes were observed in the 3 parameters at 1 hr following SCh immobilization in the 5 horses tested.

Four horses of Group 1 (trial 3), which were transported approximately 1 mile prior to the trial, were exercised over a 1-mile course and immobilized with SCh. Mean values for CPK, LDH, and SGOT activities in serum of the horses, taken while they were recumbent and at 72 hr post-immobilization, are shown in Table 3. There was no significant difference in values obtained following transport, exercise, and SCh immobilization of horses in trial 3, compared to values obtained following SCh immobilization alone in the rested horses in trial 2 ($P < 0.05$). The exercised and immobilized horses showed greater variation in response while recumbent and at 72 hr post-immobilization, in CPK, LDH, and SGOT activities, compared to rested and immobilized horses. The greater variation was attributed to variation in individual horses in response to foreign stimuli and handling methods during the exercise period.

Normal values for CPK, LDH, and SGOT activities in serum of utility horses (Group 2) are compared to 1 hr post-immobilization values for the group in Table 4. Mean values at zero-time in utility horses were not significantly different from values for rested, untrained, domestic horses (Group 1), (pooled-t, two-tailed test, $P < 0.05$). At 1 hr post-immobilization, an approximate two-told increase in CPK activity and wide variation in response was observed. The t-prime approximation of Cochran and Cox was applied in this comparison; 1 hr post-immobilization mean values were significantly increased over zero-time values (one-tailed test, $P < 0.05$).

A significant increase in LDH activity was observed in Group 2 between zero-time and 1 hr post-immobilization (paired-t, one-tailed test, $P < 0.05$).

No significant difference in SGOT mean values was observed between zero-time and 1 hr post-immobilization in these horses (paired-t, one-tailed test, $P < 0.05$).

Serum enzyme activities obtained during initial SCh immobilization of 7 feral horses (Group 3) are compared to values obtained in untrained, domestic horses, both rested (Group 1, trial 2) and following transport and exercise (Group 1, trial 3), in Table 5. Mean reference values for CPK activity in feral horses were significantly different from mean values for rested, domestic horses after SCh immobilization (t-prime, two-tailed test, $P < 0.05$). Also, the mean values for exercised domestic horses were significantly different from values for rested horses after SCh immobilization (t-prime, two-tailed test, $P < 0.05$). Mean reference values in feral horses and exercised horses after SCh immobilization were not significantly different (pooled-t, two-tailed test, $P < 0.05$).

Mean reference values for LDH activities in feral horses were significantly different from rested domestic horses after SCh immobilization, but not significantly different from exercised and immobilized horses (pooled-t, two-tailed test, $P < 0.05$).

Mean reference values for SGOT activities in feral horses were not significantly different from values in rested domestic horses after SCh immobilization (pooled-t, two-tailed test, $P < 0.05$).

## Cortisol

Normal values for serum cortisol concentrations in 12 untrained, rested, domestic horses (Group 1, trial 1) are shown in Table 6. These data are in close agreement with those reported in one study.[19]

Values for serum cortisol in 5 horses of Group 1 (trial 2), which were obtained at zero-time, while recumbent, and at 1, 24, 48, and 72 hr following SCh immobilization are listed in the same table. There was no significant difference in mean cortisol values between zero-time, while recumbent, and at 1 hr post-immobilization (paired-t, two-tailed test, $P < 0.05$). A significant lowering of mean cortisol values was observed at 24, 48, and 72 hr post-immobilization (paired-t, one-tailed test) compared to zero-time values. These data suggest that the 5 horses may have been moderately stressed prior to the trial.

Reference values for serum cortisol concentrations, obtained while the animals were recumbent following initial SCh immobilization, in untrained, rested, domestic horses; untrained and exercised domestic horses; and in feral horses, are shown in Table 7. A comparison of these data in the 3 trials demonstrates no significant differences in mean cortisol values between captive feral horses and untrained domestic horses, whether rested or exercised prior to SCh immobilization. Reference values for cortisol in captive feral horses were not significantly different from normal values in untreated domestic horses ($P < 0.05$).

Following exercise and SCh immobilization, the exercised horses' mean serum cortisol concentrations showed a marked reduction, from 7.68 to 4.1 ug/dl, at 72 hr post-immobilization (Group 1, trial 3), significant at the 0.05 level.

At 1 hr post-immobilization, cortisol concentrations in utility horses (Group 2) showed an approximate two-fold increase in mean values (2.36 to 4.85 ug/dl), which was significant (paired-t, two-tailed test, $P < 0.05$).

### Catecholamines

The range of plasma catecholamine concentrations in 12 untrained, rested, domestic horses (Group 1) was 321.00 to 777.00 pg/ml; the mean was 505.15 ± SD 147.66 pg/ml and SE 42.63. These data demonstrate that wide variation can be expected in this parameter in domestic horses.

A comparison of plasma catecholamine values obtained at zero-time, while recumbent, and at 1, 24, 48, and 72 hr following SCh immobilization in 5 rested domestic horses of Group 1 (trial 2) is shown in Table 8. Though these data did not lend themselves to statistical testing, values obtained over the 72 hr trial show that rapid increase and wide variation characterize this parameter in standing horses immobilized with SCh. Trends in response are apparent, however, and in subsequent tests a decrease in response and variation characterize the later trials.

Reference values for plasma catecholamine concentrations while the animals were recumbent following initial SCh immobilization, in untrained, rested, domestic horses; untrained and exercised domestic horses; and in feral horses, are shown in Table 9. These data indicated that variation in response was greater for the exercised and immobilized horses (Group 1, trial 2) than for rested and immobilized horses (Group 1, trial 3). A greater response in feral horses was observed and showed wide variation.

## Experiment 2: Responses in Feral Horses to Repeated Use of SCh at 72 hr Intervals

### Serum Enzymes

A graph of CPK activities in 5 feral horses of Group 3 taken at 72 hr intervals in a 30-day period is shown in Fig. 1. Moderate elevation and increased variation in CPK activity within this group was noted to day 9, followed by lowered activity to normal levels for the remaining period. The mean value throughout the experiment was 44.49 iu/l. The highest value for CPK activity was 209 iu/l in 1 horse on day 9. Mean CPK activity on day 15 was significantly lower than normal values observed on day 1 (t-prime, one-tailed test, $P < 0.05$). The correlation coefficient was -0.50 and not significant at the 0.05 level.

A graph of LDH activity in 5 feral horses of Group 3 over 30 days is shown in Fig. 2. Mean LDH activity for the 30 day experiment was 359.76 iu/l, with a range of 230.00 to 567.00 iu/l. Variation in response was relatively consistent over time; lowered LDH activity at day 30 was noted but was not significant (paired-t, one-tailed test, $P < 0.05$). The correlation coefficient was -0.77; significant at the 0.05 level.

A graph of SGOT activities in 5 feral horses of Group 3 over 30 days is shown in Fig. 3. A significant elevation in SGOT activity was observed at 72 hr, and increased activity was noted through day 9. After day 9, SGOT activity was lower and less variable to the end of the experiment. Mean SGOT activity over the 30 days was 272.87 iu/l with a range of 162 to 383 iu/l. The correlation coefficient was -0.55 and not significant ($P < 0.05$).

### Cortisol

A graph of serum cortisol concentrations in 5 feral horses of Group 3 over 30 days is shown in Fig. 4. No significant change in means was observed at 72 hr, but a marked and significant elevation was observed in cortisol values on days 6 through 12 (paired-t, one-tailed test, $P < 0.05$). This peak was followed by relatively changeable responses at each 72 hr interval and a gradual lowering of cortisol concentrations. Mean cortisol values at day 30 were not significantly higher than normal values (pooled-t, two-tailed test, $P < 0.05$). Mean cortisol concentration over 30 days was 7.36 ug/dl. No value exceeded 11.9 ug/dl. The correlation coefficient was +0.26 and not significant ($P < 0.05$).

### Catecholamines

A graph of plasma catecholamine concentrations in 5 feral horses of Group 3 over 30 days is shown in Fig. 5. Mean concentration over the 30 days was 2284.24 pg/ml and an extremely wide variation in response was noted; standard deviations often exceeded mean values. The range of catecholamine concentrations was 523.00 to 10,147.20 pg/ml, exemplifying the variability of this parameter. The correlation coefficient was +0.17 and not significant ($P < 0.05$).

## Experiment 3: Responses in Feral Horses to Repeated Use of SCh at Short Intervals

The horses used in Experiment 3 were tested concurrently with those of Experiment 2. These data are tabulated for CPK, LDH, SGOT, cortisol and catecholamines in Tables 10, 11, 12, 13, and 14, respectively. In each table, the mean and standard deviation for each horse over the course of the experiment is tabulated at the end of the column. As seen in Table 10, mean values for CPK over the 14 trials in horses 2 and 6 were markedly elevated, compared to horses 1 and 7, and the standard deviations exceeded the means. Horse 2 had an abrupt elevation in CPK activity by hr 5, which peaked on day 6 and returned to near normal levels on day 12. Horse 6 showed an exaggerated response by hr 5 and this subsided to near normal by day 12. Mean values for CPK activities for horses 1 and 7 in the 14 trials compared well with the mean for CPK in Experiment 2 (Fig. 1).

Table 11 shows the mean LDH activity for horse 7 to be considerably higher than the other 3 horses over the course of the experiment, although the variation was relatively consistent. The peak level for LDH in this horse occurred at hr 5 on day 30. Peak values for horses 1, 2, and 6 were not remarkable.

Serum GOT activities for horses 1, 6, and 7, as shown in Table 12, were relatively unchanged over the 14 trials and generally followed the line of the graph in Fig. 3 from Experiment 2. Horse 2 showed a marked elevation in SGOT activity beginning on day 1 and peaking on day 9, an extreme for the experiment of 1062 iu/l SGOT. Increased activity for this serum enzyme was noted in horse 2 for the remainder of the trial.

As noted in Table 13, the cortisol value for horse 2 was initially elevated and abruptly increased to a peak of 13.80 ug/dl by hr 5 on day 1 and decreased to a normal level on day 6. Horse 2 showed a higher mean cortisol value and greater variation than did the other 3 horses in the 14 trials.

Table 14 illustrates the extreme variability of circulating catecholamine concentrations to be expected in equines within the framework of field study conditions. No trends in response could be discerned that related, with any fidelity, to the direct effects of SCh, as used in the study.

## DISCUSSION

The practical aspects of management of feral horses prescribe that any restraint method used be efficient, practicable in a variety of field situations, and acceptable to interested agencies. Traditional methods of trapping, hazing,[m] and handling have required an expenditure of time and funds often out of proportion with management goals. Cost-effectiveness and a concern for minimizing stress and physical injury to the horses called for an examination of alternate management methods. The psychology of feral horses is such that their behavior and response to foreign stimuli is in sharp contrast to that of domestic horses. Feral horses demonstrate a variety of evasive tactics, characteristic of banding behavior, that result in considerable physical exertion before they can be restrained. A restraint method that is rapid, effective, and acceptable with regard to the physiologically adaptive capabilities of the test animal was needed. In the course of this study, it was determined that the use of SCh, as a restraint drug for free-roaming or recently captured feral horses, is one method that meets these criteria.

Experiments 1, 2, and 3 were concluded without death loss or serious injury to the horses. Primary consideration was given to the physiologic manifestations of the use of SCh for restraint. Supportive information was generated through several trials conducted in domestic horses whose physiologic status could be determined prior to the use of the drug. The results obtained were compared to those found after initial SCh immobilization. Extrapolation of results recorded in feral horses to those of domestic horses provides strong evidence that no difference exists between domestic and feral horses with respect to normal values for the serum enzymes, CPK and SGOT, and the circulating cortiosteroid, cortisol. Similar evidence supports the premise that serum LDH activity and circulating catecholamine levels in domestic and feral horses are similar.

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[m] Moving or herding horses to a point or separating them in captive situations.

The physiologic and pathologic changes concomitant with strenuous muscular activity in horses have been reviewed.[11,12] These changes are recognized to occupy a gradient from mild lactic acid accumulation and lowered pH in muscle tissue to profound alterations in muscle metabolism leading to myositis and skeletal myopathy with resulting myoglobinemia and myoglobinuria. The "tying-up syndrome" is considered to be a milder form of the paralytic myopathy known as "azoturia" or paralytic myoglobinuria, the former differing from the latter only in degree.[10]

Observations made throughout this study did not disclose evidence of myoglobin release from the skeletal musculature nor suggest that severe impairment of locomotor muscles occurred. Horse 2 in Experiment 3, which had been immobilized 4 times within 6 hr on day 1, showed a noticeable degree of change in his usual gait by the end of hr 3 on day 1. Daily observation of this horse supported the suggestion that a state of myositis was present, and the laboratory results over the following 2 weeks confirmed that a threatening level of exhaustion had been approached on day 1. The degree to which the direct effects of SCh contributed to this derangement is open to question since, of all the horses, this horse was the most evasive. Horse 6, the younger of the 2 horses treated repeatedly on day 1, showed no clinical nor laboratory evidence that repeated use of SCh at short intervals did result in clinical signs of myositis.

In a consideration of possible myocardial damage resulting from SCh immobilization techniques, the serum enzyme activities and the comparative disappearance rates of these enzymes were examined. Previous investigators have put forth the argument that elevated levels of CPK activity are indicative of muscle necrosis and that early subsidence in this serum enzyme is evidence of early repair in a non-progressive myopathy. High and sustained CPK activities were considered to result from release of this enzyme from the mitochondria as a result of cell necrosis, as in myocardial infarction. In humans, about 1 percent of CPK activity in skeletal muscle is in the sarcoplasmic reticulum, about 25 percent is bound to the skeletal myofibril, and the remainder presumably is in the mitochondria.[15] In untrained persons, serum CPK activities could increase 20-fold over normal levels as a result of strenuous exercise. This evidence suggests that a portion of the increased CPK activity in horses, resulting from unaccustomed exertion, originates from the sarcoplasmic reticulum or diffuses from neighboring myofibrils without the loss of mitochondrial integrity that is associated with cellular necrosis. The rapid and transient elevation of CPK activities noted from horses 2 and 6 in this study would support that suggestion. Even with repeated SCh immobilization at 72 hr intervals, elevated CPK activities in these horses did not persist over 6 days. On this basis, although presumptive diagnosis of myocardial damage would ultimately depend upon specific CPK isoenzyme studies, it was considered unlikely that myocardial injury, accompanied by cellular necrosis, occurred in any of the feral horses.

With the exception of horse 2 in Experiment 3, SGOT activity changes in the other feral horses in both experiments were not remarkable. Serum GOT is released from muscle fibers after strenuous muscular activity more slowly than CPK or LDH and has a protracted disappearance rate. Elevations in SGOT resulting from excessive muscular activity can be expected to rise sharply after the first 24 hr and to persist for 2 or 3 weeks before returning to normal levels.

The importance of LDH as an indicator of skeletal muscle damage is in question since elevations in activity of this serum enzyme occur after only moderate levels of exercise. In rested domestic horses, LDH activities were significantly higher than normal at 48 and 72 hr after SCh immobilization. Exercised horses showed elevated LDH values before SCH immobilization. In the feral horses the response, as reflected by increased LDH activity, corresponded to the duration of exercise prior to being immobilized. Horse 7 in Experiment 3, which had been immobilized 4 times on day 30, was usually the last horse immobilized in each trial, and LDH activity in this horse was rather consistently higher than in the other horses. Horses immobilized in the earlier hours generally had lower LDH values. It is evident that LDH levels, in untrained horses after SCh immobilization, relate more to the degree and extent of exertion than to direct evidence of cellular injury resulting from the use of the drug.

In contrast, CPK and SGOT activities would appear to be valuable indices of marked changes at the cellular level. Simultaneous determination of CPK and SGOT activities has been suggested as a useful diagnostic and prognostic method in evaluation of skeletal myopathies in horses.[11] Short-term elevations in the levels of these enzymes can be considered to reflect minimal alterations in active muscle tissue. Prolonged elevations of SGOT activity after strenuous exercise, unaccompanied by persistent elevation in CPK activity, signals a more serious, but not irreversible, alteration in the locomotor muscle cells. Sustained elevations of both CPK and SGOT indicate that profound and possibly irreversible changes characterized by inflammation and cellular necrosis may have occurred.

The specific levels of activity at which these serum enzymes may indicate substantial muscle tissue injury have not been established. Serum GOT activities exceeding the approximate range of 480 to 500 iu/l have been associated with clinical signs of myopathy in certain horses.[10] However, higher levels have been reported in horses that showed no clinical evidence of myopathy. Wide variation in CPK levels was observed in horses exhibiting clinical signs of paralytic myoglobinuria.[11] It would seem that the magnitude and rate of elevation of these serum enzyme activities would serve as an indicator of impending myopathy. Two-to-three fold increases in both CPK and SGOT activities over established normal values in any single test should be considered as indicating existent, or threatened but clinically inapparent, myopathy. On that basis, horse 2 in Experiment 3 was judged to have had a subclinical myositis manifest between days 3 and 24.

The spectrum of physical exercise, from mild and beneficial to extreme and life-threatening, has long been recognized as a stressor, in the usually offered interpretation of stress. A more colloquial interpretation of stress, referred to variously as physical stress, capture stress and/or locomotory stress, that concerns the physiologic perturbations resulting from and pathologic manifestations of physical exertion, has been offered.[3] The literature contains references to stress myositis, stress myopathy, and lethal levels of stress, the implication being that manifestations of stress take different forms depending upon the nature of the stressor. In this discussion, the latter interpretation is avoided.

Repeated use of SCh as a restraining agent had a somewhat cumulative effect on the pituitary-adrenocortical axis in feral horses. Trends early in the course of Experiment 2 showed decided elevations in serum cortisol levels up to day 12, with a less pronounced influence later. The general trend for the experiment was for moderately increased cortisol secretion in early trials and a reduced variation characterizing the later trials. Obviously, these responses were dependent upon individual variation relating to events preceding the immobilization attempt, including recovery time from the previous use of the drug and the degree of apprehensiveness among the horses at the time of the trial.

Interpretation of possible interrelationships of serum cortisol concentrations and serum enzyme activities was considered. Analogs of cortisol have been shown to reduce the efflux of enzymes from active muscle tissue in horses treated prior to exercise.[12] The mechanism by which glucocorticoids exert this protective influence on the muscle cell membrane is not fully understood, but is believed to be related to known restorative and anti-inflammatory properties of this class of hormone. The observation that as endogenous cortisol values increased, serum enzyme levels decreased, suggests a probable correlation of these results in feral horses. However, this correlation was not statistically apparent in the present study.

Insofar as serum cortisol concentrations can be employed as an index of stress, it was seen in this study that both frequent provocation of feral horses and the use of SCh contribute to the clinical expression of stress. The degree to which each stressor influenced the response in feral horses cannot be stated with certainty, but on the basis of results obtained in rested domestic horses, the effect of the drug alone as a stressor is regarded as being minimal. The evasiveness and confusion of feral horses, during hazing, more likely had a greater impact on the expression of stress.

It was apparent early in the study that an interpretation of the relationship of circulating catecholamine levels to changes in the other physiologic parameters in feral horses was not possible within the design of these experiments. Establishing normal values in this parameter will require a different experimental approach. Studies under carefully controlled experimental conditions may provide data that is amenable to statistical evaluation.

The role of circulating catecholamines as a probable factor in the increased permeability of muscle cell membranes after exercise has been proposed.[15] The contribution of catecholamines to the efflux of serum enzymes and of potassium is ranked alongside cellular hypoxia, hypercapnia and acidosis as probable causes of cellular membrane permeability changes. It may be shown, with further study, that the local effects of catecholamines serve a restorative function in hastening efflux of metabolites from active muscle cells.

Another fertile area for further study involves the availability of modern telemetric equipment and the practicability of instrumentation of free-roaming equidae by the surgical implantation of sensors. Stress-related parameters such as heart rate, respiratory rate, and arterial blood pressure, as well as electrocardiographic events, are possible to monitor through the use of these devices. The proper facilities for the pilot studies in this imaginative technology are required before a more complete elucidation of stress in feral equidae will be realized.

## CONCLUSIONS

Succinylcholine chloride as an immobilizing agent was determined to be an effective drug for capture and short-term restraint when administered intramuscularly to unapproachable horses.

Reference levels of the serum enzymes, CPK and SGOT, in feral horses in captivity compare well with normal levels in rested domestic horses not in training. The dynamic behavior of the serum enzymes and of circulating catecholamines supports the premise that baseline levels of LDH and of plasma catecholamines in domestic and feral horses are not significantly disparate. Serum cortisol concentrations in rested and untrained domestic horses and in feral horses in captivity are the same.

Responses to SCh immobilization in feral horses followed, in essentially parallel fashion, those of domestic horses in the first 1 to 3 hr after recovery. Responses to infrequent use (days) of SCh in feral horses caused minimal alterations in serum enzyme and corticosteroid levels and these could be expected to return to normal within 72 hr. Repeated use of SCh at 72 hr intervals resulted in significant elevations in activity of the serum enzymes studied, sometime in the course of the experiment. These responses were seen to be cumulative over time in the early trials but generally diminutive in later trials. These effects were considered to be related to increased tolerance to the method derived through adaptation and training.

Repeated use of SCh (hours) in intractable horses was seen to result in exaggerated responses, especially if the animal was compromised by prior stress or physical exhaustion. Life-threatening levels of exertion in the hazing period, compounded by the depolarizing effects of the drug, could lead to skeletal muscle cellular hypoxia, hypercapnia, and acidosis progressing to irreversible sequellae. In light of this, it is inadvisable to superimpose the distress of chemical immobilization upon physiologically compromised animals. Horses that have recently been trapped, hazed for extended periods, or subjected to long transport may be experiencing elevated serum enzyme levels that approximate threatening levels. The additional distress of chemical restraint methods is contraindicated. In the same light, repeated use of SCh within short intervals, measured in hours, is not justified. The effects of training are considered to increase physical tolerance to repeated use of SCh in horses.

On the basis of the limited number of test animals in Experiment 3, in which SCh was used repeatedly at short intervals, only general statements can be made relative to age differences in response to SCh immobilization in feral horses. The consensus is that juvenile horses are more tolerant than adult horses, who tend to be especially evasive in captive situations and more adherent to banding behavior when approached by humans.

Experienced personnel may employ the methods described in a number of field situations for management of intractable horses. In rested captive horses, the use of SCh, as a casting agent for short restraint periods, has many advantages over traditional handling methods. Sufficient time to complete the majority of management procedures is afforded with this restraint technique; additional restraint methods such as sedation, tranquilization, or the application of harness may be used, as required, to extend the period of restraint. In the hands of skilled operators, applying proper judgment, this method is seen to be safe and humane. The use of SCh at 2 to 3 day intervals, if required, should not pose a threat to otherwise normal captive feral horses.

The assessment of SCh, as a drug to be used in capture and restraint of free-roaming or captive feral horses on the basis of humane and economic considerations, will have to await the deliberations of the interested agencies. The drug and the technique are suggested as a valuable procedure for future studies with known chemical restraint agents and others that may be developed.

## SUMMARY

Reference values for the serum enzymes CPK, LDH, and SGOT were evaluated in captive feral horses by comparison with rested, exercised, and utility-type domestic horses after SCh immobilization. Serum cortisol and plasma catecholamine concentrations in feral horses were described. The results indicated no difference in these parameters between captive feral horses and untrained domestic horses.

The physiologic alterations resulting from repeated short-interval use and repeated long-term use of SCh as a restraint agent in captive feral horses were examined. Minimal and impermanent alterations in these parameters were observed, which suggested that prolonged or irreversible sequellae did not develop.

The method was considered safe and humane for use in feral horses. The effectiveness of SCh after intramuscular administration, and the practical use of it in management of unapproachable horses, suggests the method as a valuable procedure for study of alternate restraint techniques in feral equidae.

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# TABLES

## TABLE 1

## NORMAL VALUES FOR CREATINE PHOSPHOKINASE (CPK), LACTATE DEHYDROGENASE (LDH), AND GLUTAMATE-OXALOACETATE TRANSAMINASE (SGOT) ACTIVITIES* IN SERUM OF RESTED, UNTRAINED, DOMESTIC HORSES

| Group | Trial | Enzyme | n[†] | $\bar{x} \pm$ SD[†] | SE[†] |
|---|---|---|---|---|---|
| 1 | 1 | CPK | 12 | 40.33 ± 17.42 | 5.02 |
|  |  | LDH |  | 255.58 ± 53.95 | 15.57 |
|  |  | SGOT |  | 241.67 ± 15.55 | 4.49 |

*international units per liter

[†] n = sample numbers

$\bar{x} \pm$ SD = mean ± standard deviation

SE = standard error of mean

## TABLE 2

## VALUES FOR CREATINE PHOSPHOKINASE (CPK), LACTATE DEHYDROGENASE (LDH), AND GLUTAMATE-OXALOACETATE TRANSAMINASE (SGOT) ACTIVITIES*, IN RESPONSE TO SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION, IN SERUM OF RESTED, UNTRAINED, DOMESTIC HORSES

| Group | Trial | Enzyme | n[†] | Hour | $\bar{x}$ ± SD[†] | SE[†] |
|---|---|---|---|---|---|---|
| 1 | 2 | CPK | 5 | OT[‡] | 43.80 ± 13.14 | 5.88 |
| | | | | D[§] | 43.00 ± 2.74 | 1.22 |
| | | | | 1 | 56.00 ± 16.36 | 7.32 |
| | | | | 24 | 75.00 ± 10.00 | 4.47 |
| | | | | 48 | 117.80 ± 143.54 | 64.19 |
| | | | | 72 | 44.00 ± 11.94 | 5.34 |
| 1 | 2 | LDH | 5 | OT | 234.80 ± 62.78 | 28.08 |
| | | | | D | 256.80 ± 68.82 | 30.78 |
| | | | | 1 | 246.60 ± 69.81 | 31.22 |
| | | | | 24 | 280.80 ± 71.55 | 32.00 |
| | | | | 48 | 304.00 ± 68.89 | 30.81 |
| | | | | 72 | 289.60 ± 62.35 | 27.88 |
| 1 | 2 | SGOT | 5 | OT | 204.80 ± 30.01 | 13.42 |
| | | | | D | 219.00 ± 28.43 | 12.71 |
| | | | | 1 | 212.80 ± 28.75 | 12.86 |
| | | | | 24 | 265.60 ± 72.15 | 32.27 |
| | | | | 48 | 263.60 ± 45.13 | 20.18 |
| | | | | 72 | 241.40 ± 22.46 | 10.04 |

[*] international units per liter

[†] n = sample number
$\bar{x}$ ± SD = mean ± standard deviation
SE = standard error of mean

[‡] OT = zero time

[§] D = while recumbent

## TABLE 3

## VALUES FOR CREATINE PHOSPHOKINASE (CPK), LACTATE DEHYDROGENASE (LDH), AND GLUTAMATE-OXALOACETATE TRANSAMINASE (SGOT) ACTIVITIES*, DURING SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION FOLLOWING TRANSPORT AND EXERCISE, IN SERUM OF UNTRAINED, DOMESTIC HORSES AND AT 72 HOURS POST-IMMOBILIZATION

| Group | Trial | Enzyme | n[†] | Hour | $\bar{x} \pm$ SD[†] | SE[†] |
|---|---|---|---|---|---|---|
| 1 | 3 | CPK | 4 | D[‡] | 40.50 ± 12.56 | 6.28 |
|  |  |  |  | 72 | 34.25 ± 8.10 | 4.05 |
|  |  | LDH | 4 | D | 307.00 ± 80.80 | 40.40 |
|  |  |  |  | 72 | 336.00 ± 94.11 | 47.06 |
|  |  | SGOT |  | D | 287.00 ± 130.59 | 65.30 |
|  |  |  |  | 72 | 292.25 ± 100.79 | 50.40 |

[*] international units per liter

[†] n = sample number

$\bar{x} \pm$ SD = mean ± standard deviation

SE = standard error of mean

[‡] D = while recumbent

TABLE 4

VALUES FOR CREATINE PHOSPHOKINASE (CPK), LACTATE DEHYDROGENASE (LDH), AND GLUTAMATE-OXALOACTETATE TRANSAMINASE (SGOT) ACTIVITIES*, AT ZERO-TIME AND ONE HOUR FOLLOWING SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION, IN SERUM OF RESTED, UTILITY HORSES

| Group | Enzyme | n[†] | Hour | $\bar{x}$ ± SD[†] | SE[†] |
|---|---|---|---|---|---|
| 2 | CPK | 19 | OT[‡] | 51.89 ± 20.12 | 4.62 |
| | | | 1 | 102.10 ± 62.53 | 14.35 |
| | LDH | 19 | OT | 278.68 ± 70.42 | 16.16 |
| | | | 1 | 302.84 ± 81.02 | 18.49 |
| | SGOT | 19 | OT | 273.16 ± 69.04 | 15.84 |
| | | | 1 | 261.68 ± 80.80 | 18.54 |

[*] international units per liter
[†] n = sample number
$\bar{x}$ ± SD = mean ± standard deviation
SE = standard error of mean
[‡] OT = zero time

### TABLE 5

### REFERENCE VALUES FOR CREATINE PHOSPHOKINASE (CPK), LACTATE DEHYDROGENASE (LDH), AND GLUTAMATE-OXALOACETATE TRANSAMINASE (SGOT) ACTIVITIES*, DURING INITIAL SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION, IN SERUM OF CAPTIVE, FERAL HORSES AND UNTRAINED, DOMESTIC HORSES

| Group[‡] | Trial | Enzyme | n[†] | $\bar{x} \pm$ SD[†] | SE[†] |
|---|---|---|---|---|---|
| 1 | 2 | CPK | 5 | 43.00 ± 2.74 | 1.22 |
| | | LDH | | 256.80 ± 68.82 | 30.78 |
| | | SGOT | | 219.00 ± 28.43 | 12.71 |
| 1 | 3 | CPK | 4 | 40.50 ± 12.56 | 6.28 |
| | | LDH | | 307.00 ± 80.80 | 40.40 |
| | | SGOT | | 287.00 ± 130.59 | 65.30 |
| 3 | 1 | CPK | 7 | 41.43 ± 12.15 | 4.59 |
| | | LDH | | 387.43 ± 91.21 | 34.48 |
| | | SGOT | | 235.29 ± 46.70 | 17.65 |

*international units per liter

[†] n = sample numbers

$\bar{x} \pm$ SD = mean ± standard deviation

SE = standard error of mean

[‡] Group 1, trial 2, were rested, domestic horses; Group 1, trial 3, were exercised, domestic horses; Group 3, trial 1, were captive, feral horses.

## TABLE 6

## NORMAL VALUES AND REFERENCE VALUES FOR SERUM CORTISOL CONCENTRATIONS* OBTAINED FOLLOWING SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION OF RESTED DOMESTIC HORSES

| Group[‖] | Trial | Hour | n[†] | $\overline{x}$ ± SD[†] | SE[†] |
|---|---|---|---|---|---|
| 1 | 1 | OT[‡] | 12 | 7.53 ± 2.47 | 0.71 |
| 1 | 2 | OT | 5 | 8.28 ± 1.97 | 0.88 |
|  |  | D[§] |  | 7.96 ± 2.66 | 1.19 |
|  |  | 1 |  | 8.32 ± 2.37 | 1.06 |
|  |  | 24 |  | 6.68 ± 1.14 | 0.51 |
|  |  | 48 |  | 5.80 ± 1.54 | 0.69 |
|  |  | 72 |  | 6.32 ± 1.18 | 0.53 |

[*] microprams per deciliter

[†] n = sample number

$\overline{x}$ ± SD = mean ± standard deviation

SE = standard error of mean

[‡] OT = zero-time

[§] D = while recumbent

[‖] Group 1, trial 1: rested, untreated, domestic horses

Group 1, trial 2: rested and immobilized, domestic horses

# TABLE 7

## REFERENCE VALUES FOR SERUM CORTISOL CONCENTRATIONS* DURING INITIAL SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION, OF CAPTIVE, FERAL HORSES AND UNTRAINED, DOMESTIC HORSES

| Group[‡] | Trial | n[†] | $\bar{x} \pm$ SD[†] | SE[†] |
|---|---|---|---|---|
| 1 | 2 | 5 | 7.96 ± 2.66 | 1.19 |
| 1 | 3 | 4 | 7.68 ± 2.14 | 1.07 |
| 3 | 1 | 6 | 6.90 ± 1.54 | 0.63 |

*micrograms per deciliter
n = sample number
$\bar{x} \pm$ SD = mean ± standard deviation
SE = standard error of mean
Group 1, trial 2: rested, domestic horses
Group 1, trial 3: exercised, domestic horses
Group 3, trial 1: captive, feral horses

# TABLE 8

# VALUES FOR PLASMA CATECHOLAMINE CONCENTRATIONS* OBTAINED FOLLOWING SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION OF RESTED, DOMESTIC HORSES

| Group | Trial | Hour | n[†] | $\bar{x} \pm$ SD[†] | SE[†] |
|---|---|---|---|---|---|
| 1 | 2 | OT[‡] | 5 | 592.40 ± 83.01 | 37.12 |
| | | D[§] | | 1157.00 ± 462.58 | 206.87 |
| | | 1 | | 636.60 ± 152.50 | 68.20 |
| | | 24 | | 728.40 ± 269.32 | 120.45 |
| | | 48 | | 422.20 ± 159.93 | 71.52 |
| | | 72 | | 328.20 ± 36.02 | 16.11 |

[*] picograms per milliliter
[†] n = sample number
$\bar{x} \pm$ SD = mean ± standard deviation
SE = standard error of mean
[‡] OT = zero-time
[§] D = while recumbent

## TABLE 9

## REFERENCE VALUES FOR PLASMA CATECHOLAMINE CONCENTRATIONS*, DURING INITIAL SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION, OF CAPTIVE, FERAL HORSES AND UNTRAINED, DOMESTIC HORSES

| Group‡ | Trial | n† | $\bar{x} \pm$ SD† | SE† |
|---|---|---|---|---|
| 1 | 2 | 5 | 1157.00 ± 462.58 | 206.87 |
| 1 | 3 | 4 | 1325.15 ± 1536.69 | 768.35 |
| 3 | 1 | 6 | 1641.64 ± 965.76 | 394.27 |

*picograms per milliliter
n = sample number
$\bar{x} \pm$ SD = standard deviation
SE = standard error of mean
Group 1, trial 2: rested domestic horses
Group 1, trial 3: exercised, domestic horses
Group 3, trial 1: captive, feral horses

### TABLE 10

### SERUM CREATINE PHOSPHOKINASE ACTIVITIES* IN FOUR FERAL HORSES AFTER SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION IN 14 TRIALS OVER 30 DAYS

| Day | Hour | Horse 1 | Horse 2 | Horse 6 | Horse 7 |
|---|---|---|---|---|---|
| 1 | 0 | 50 | 35 | 50 | 45 |
|  | 1 | .. | 45 | 20 | .. |
|  | 3 | .. | 125 | 309 | .. |
|  | 5 | .. | 120 | 688 | .. |
| 3 |  | 50 | 90 | 125 | 30 |
| 6 |  | 35 | 479 | 145 | 40 |
| 9 |  | 35 | 105 | 70 | 35 |
| 12 |  | 40 | 60 | 60 | 25 |
| 15 |  | 30 | 30 | 17 | 20 |
| 18 |  | 17 | 25 | 27 | 40 |
| 21 |  | 70 | 20 | 30 | 32 |
| 24 |  | 25 | 25 | 35 | 37 |
| 27 |  | 20 | 100 | 45 | 25 |
| 30 | 0 | 20 | 130 | 40 | 45 |
|  | 1 | 30 | .. | .. | 40 |
|  | 3 | 50 | .. | .. | 50 |
|  | 5 | .. | .. | .. | 65 |
| mean[†] |  | 36.31 | 92.07 | 118.64 | 37.77 |
| SD[‡] |  | (15.35) | (117.74) | (181.14) | (11.62) |

[*] international units per liter of serum

[†] mean for 14 trials in 30 days

[‡] standard deviation of the mean

## TABLE 11

## SERUM LACTATE DEHYDROGENASE ACTIVITIES* IN FOUR FERAL HORSES AFTER SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION IN 14 TRIALS OVER 30 DAYS

| Day | Hour | Horse 1 | Horse 2 | Horse 6 | Horse 7 |
|---|---|---|---|---|---|
| 1 | 0 | 374 | 309 | 369 | 553 |
| | 1 | ... | 337 | 326 | ... |
| | 3 | ... | 384 | 379 | ... |
| | 5 | ... | 403 | 434 | ... |
| 3 | | 401 | 306 | 283 | 476 |
| 6 | | 374 | 461 | 280 | 470 |
| 9 | | 418 | 402 | 413 | 283 |
| 12 | | 407 | 349 | 268 | 506 |
| 15 | | 336 | 269 | 221 | 471 |
| 18 | | 283 | 243 | 227 | 576 |
| 21 | | 405 | 270 | 265 | 479 |
| 24 | | 311 | 208 | 294 | 529 |
| 27 | | 387 | 294 | 256 | 457 |
| 30 | 0 | 405 | 273 | 331 | 504 |
| | 1 | 391 | ... | ... | 516 |
| | 3 | 401 | ... | ... | 559 |
| | 5 | ... | ... | ... | 648 |
| mean[†] | | 376.38 | 322.00 | 314.00 | 501.93 |
| SD[‡] | | (41.32) | (70.95) | (63.43) | (81.69) |

[*] international units per liter of serum

[†] mean for 14 trials in 30 days

[‡] standard deviation of the mean

## TABLE 12

## SERUM GLUTAMATE-OXALACETATE TRANSAMINASE ACTIVITIES* IN FOUR FERAL HORSES AFTER SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION IN 14 TRIALS OVER 30 DAYS

| Day | Hour | Horse 1 | Horse 2 | Horse 6 | Horse 7 |
|---|---|---|---|---|---|
| 1 | 0 | 192 | 251 | 234 | 162 |
|  | 1 | ... | 245 | 239 | ... |
|  | 3 | ... | 276 | 261 | ... |
|  | 5 | ... | 281 | 288 | ... |
| 3 |  | 329 | 421 | 331 | 324 |
| 6 |  | 303 | ... | 279 | 309 |
| 9 |  | 355 | 1062 | 268 | 255 |
| 12 |  | 369 | 864 | 254 | 308 |
| 15 |  | 295 | 666 | 216 | 268 |
| 18 |  | 194 | 483 | 209 | 326 |
| 21 |  | 258 | 425 | 205 | 268 |
| 24 |  | 209 | 323 | 214 | 278 |
| 27 |  | 237 | 344 | 242 | 262 |
| 30 | 0 | 231 | 301 | 242 | 263 |
|  | 1 | 228 | ... | ... | 263 |
|  | 3 | 206 | ... | ... | 276 |
|  | 5 | ... | ... | ... | 279 |
| mean† |  | 262.00 | 457.08 | 248.71 | 274.36 |
| SD‡ |  | (61.63) | (255.69) | (35.02) | (40.18) |

*international units per liter of serum
†mean for 14 trials in 30 days
‡standard deviation of the mean

## TABLE 13

## SERUM CORTISOL CONCENTRATIONS[*] IN FOUR FERAL HORSES AFTER SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION IN 14 TRIALS OVER 30 DAYS

| Day | Hour | Horse 1 | Horse 2 | Horse 6 | Horse 7 |
|---|---|---|---|---|---|
| 1 | 0 | ... | 9.1 | 6.5 | 4.5 |
|  | 1 | ... | 12.6 | 7.8 | ... |
|  | 3 | ... | 11.9 | 6.9 | ... |
|  | 5 | ... | 13.8 | 6.4 | ... |
| 3 |  | 5.7 | 12.2 | 5.2 | 5.7 |
| 6 |  | 10.4 | 6.7 | 7.1 | 5.1 |
| 9 |  | 5.8 | 7.6 | 6.7 | 6.5 |
| 12 |  | 9.0 | 7.4 | 8.6 | 8.3 |
| 15 |  | 10.0 | 6.3 | 8.2 | 4.8 |
| 18 |  | 8.6 | 6.2 | 7.7 | 8.0 |
| 21 |  | 8.4 | 5.8 | 5.7 | 5.5 |
| 24 |  | 7.3 | 6.2 | 6.5 | 8.3 |
| 27 |  | 8.0 | 6.0 | 5.7 | 8.0 |
| 30 | 0 | 9.2 | 7.7 | 5.9 | 7.9 |
|  | 1 | 9.3 | ... | ... | 8.0 |
|  | 3 | 5.3 | ... | ... | 5.8 |
|  | 5 | 5.6 | ... | ... | 9.6 |
| mean[†] |  | 7.89 | 8.54 | 6.78 | 6.86 |
| SD[‡] |  | (1.78) | (2.85) | (1.01) | (1.62) |

[*] micrograms per deciliter

[†] mean for 14 trials in 30 days

[‡] standard deviation of the mean

## TABLE 14

## PLASMA CATECHOLAMINE CONCENTRATIONS[*] IN FOUR FERAL HORSES AFTER SUCCINYLCHOLINE CHLORIDE IMMOBILIZATION IN 14 TRIALS OVER 30 DAYS

| Day | Hour | Horse 1 | Horse 2 | Horse 6 | Horse 7 |
|---|---|---|---|---|---|
| 1 | 0 | 1846.12 | 1299.43 | 746.60 | 2246.60 |
| | 1 | .... | 849.89 | 501.40 | .... |
| | 3 | .... | 1546.55 | 1922.20 | .... |
| | 5 | .... | 1658.50 | 947.00 | .... |
| 3 | | 689.50 | 685.50 | 1314.80 | 1010.00 |
| 6 | | 970.40 | 3999.50 | 617.70 | 765.18 |
| 9 | | 2883.18 | 3345.36 | 1367.24 | 1265.87 |
| 12 | | 4615.21 | 1235.61 | 550.14 | 736.00 |
| 15 | | 4655.79 | 1528.83 | 566.50 | 6595.00 |
| 18 | | 6001.40 | 643.60 | 616.90 | 5657.40 |
| 21 | | 8521.80 | 1618.30 | 628.30 | 698.70 |
| 24 | | 7022.50 | 937.00 | 523.00 | 716.30 |
| 27 | | 928.60 | 1317.80 | 7955.70 | 8040.00 |
| 30 | 0 | 7219.80 | 2204.60 | 1528.40 | 855.60 |
| | 1 | 3284.30 | .... | .... | 1149.80 |
| | 3 | 7125.60 | .... | .... | 511.10 |
| | 5 | 4993.20 | .... | .... | 208.50 |
| mean[†] | | 4339.81 | 1633.60 | 1413.28 | 2175.43 |
| SD[‡] | | (2629.31) | (969.59) | (1935.87) | (2572.69) |

[*] picogram per milliliter
[†] mean for 14 trials in 30 days
[‡] standard deviation of the mean

# APPENDIX B

# FIGURES

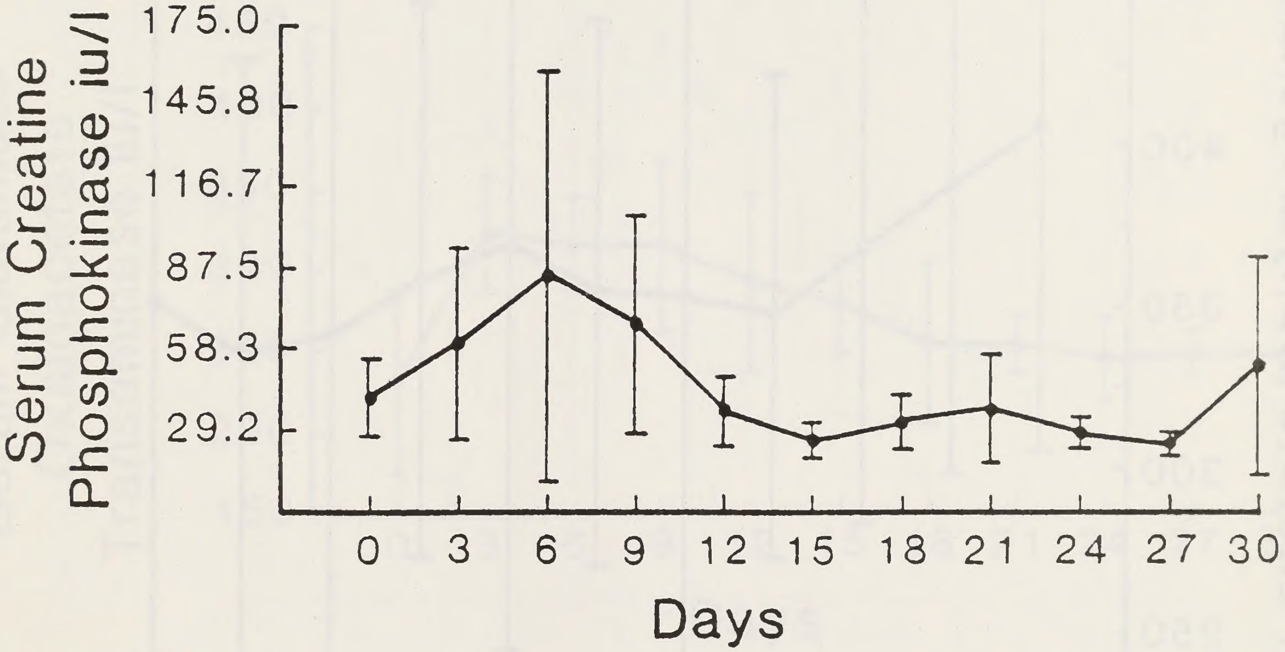

Fig. 1--Serum creatine phosphokinase activities after succinylcholine chloride immobilization of captive feral horses at 72 hour intervals for 30 days. Values shown are means ± standard deviations.

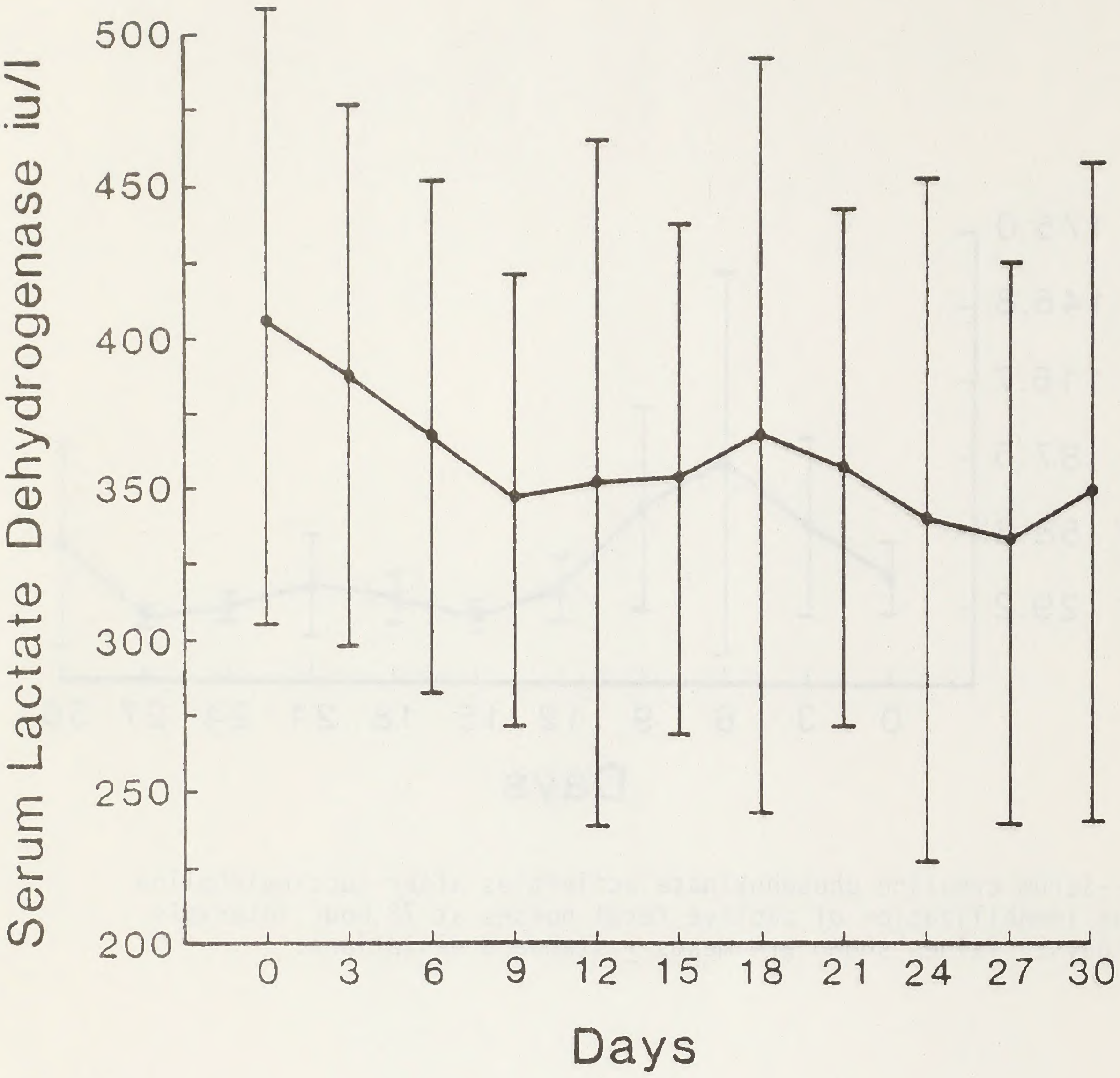

Fig. 2--Serum lactate dehydrogenase activities after succinylcholine chloride immobilization of captive feral horses at 72 hour intervals for 30 days. Values shown are means ± standard deviations.

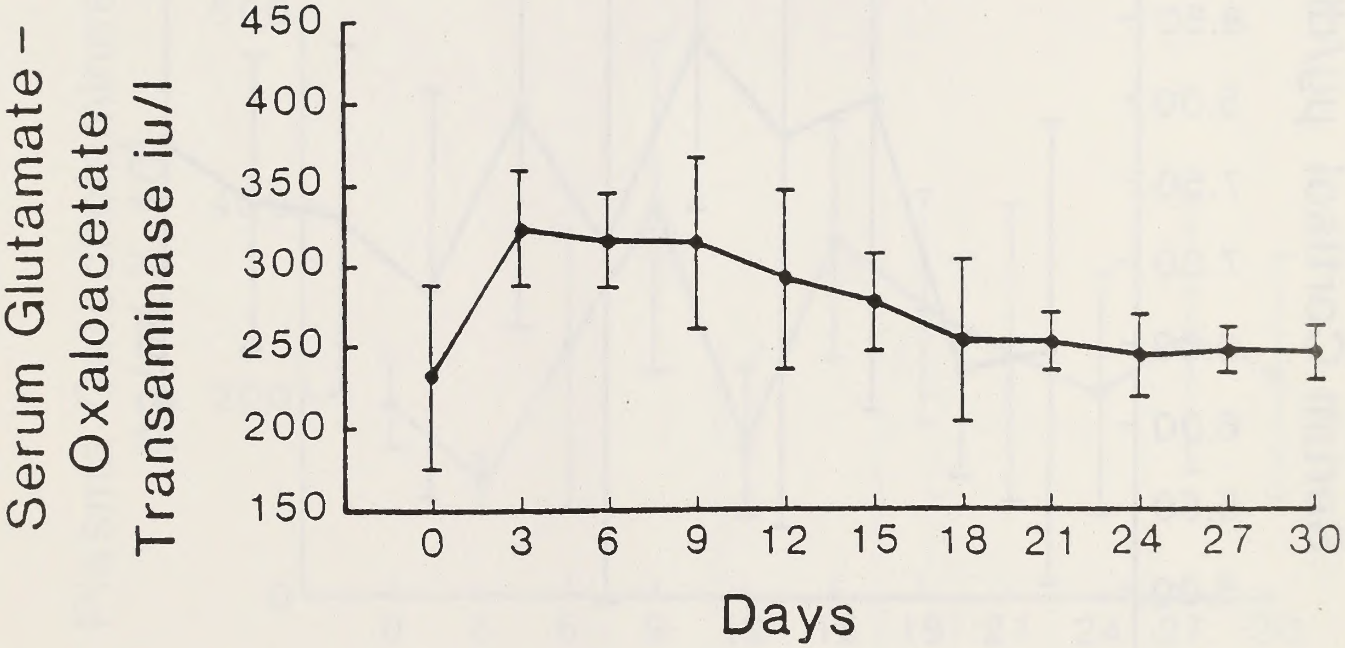

Fig 3--Serum glutamate-oxaloacetate transaminase activities after succinylcholine chloride immobilization of captive feral horses at 72 hour intervals for 30 days. Values shown are means ± standard deviations.

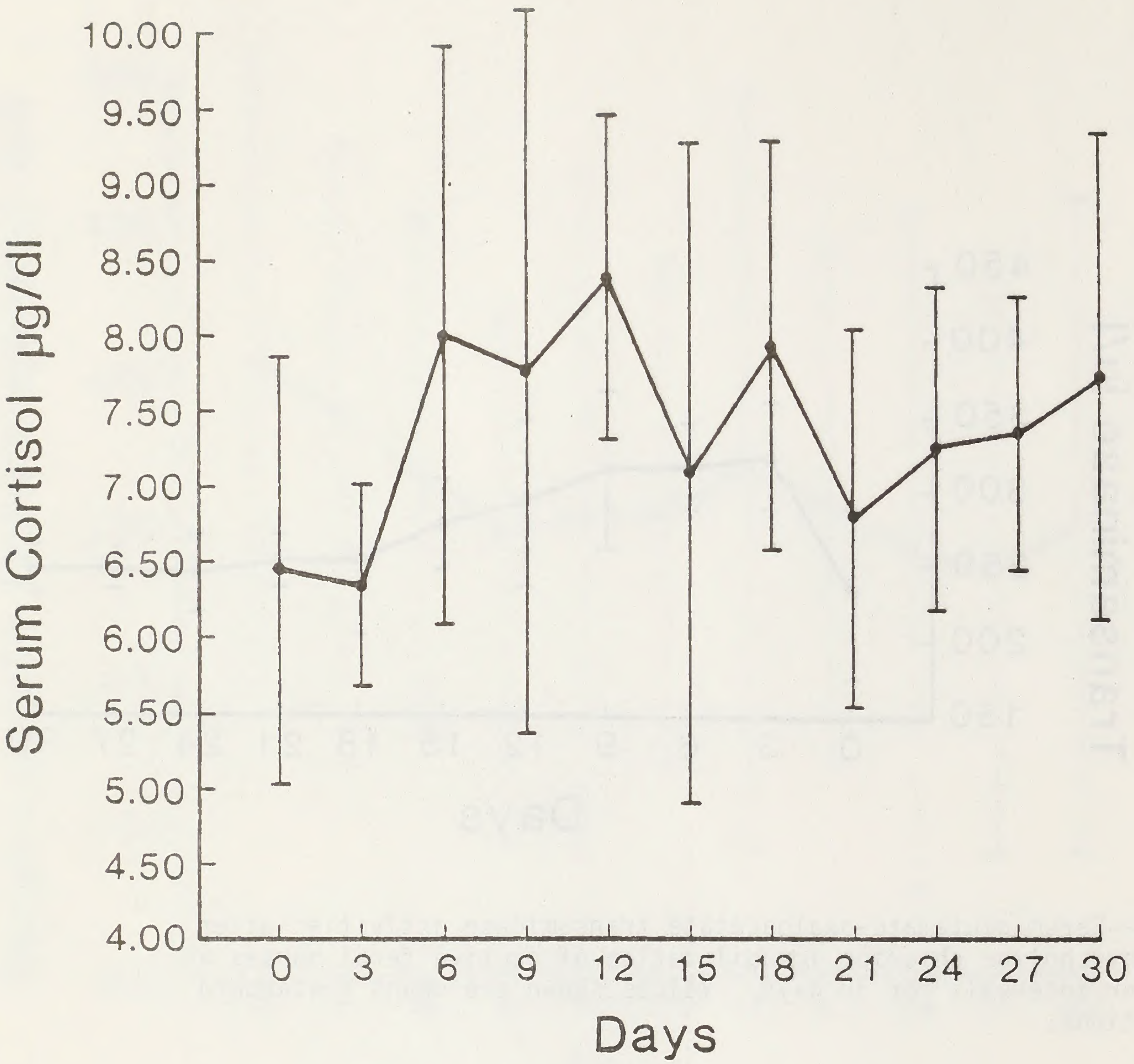

Fig. 4--Serum cortisol concentrations after succinylcholine chloride immobilization of captive feral horses at 72 hour intervals for 30 days. Values shown are means ± standard deviations.

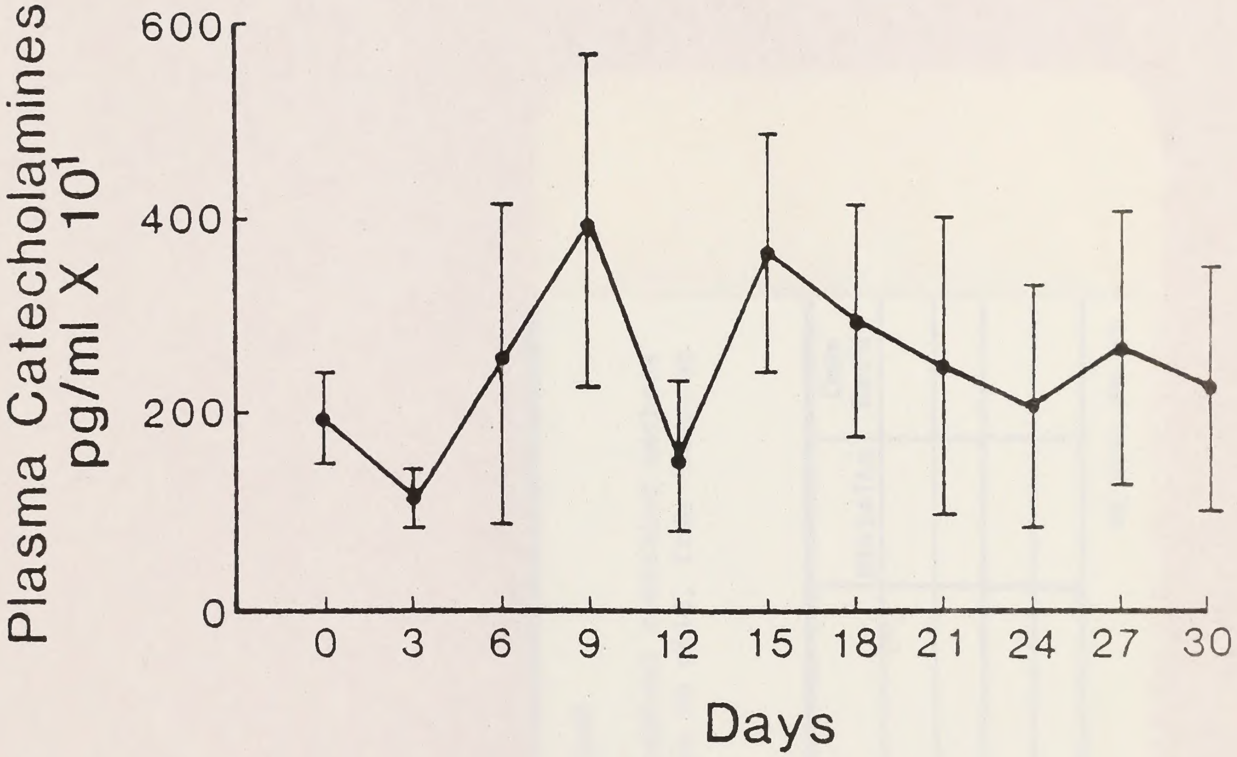

Fig. 5--Plasma catecholamine concentrations after succinylcholine chloride immobilization of captive feral horses at 72 hour intervals for 30 days. Values shown are means ± standard error of the means.

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